Lose the Wrappers – A New Approach for Estimating Project Support Functions

A Battle Between Common Sense and Math/Statistics

Preliminary Results

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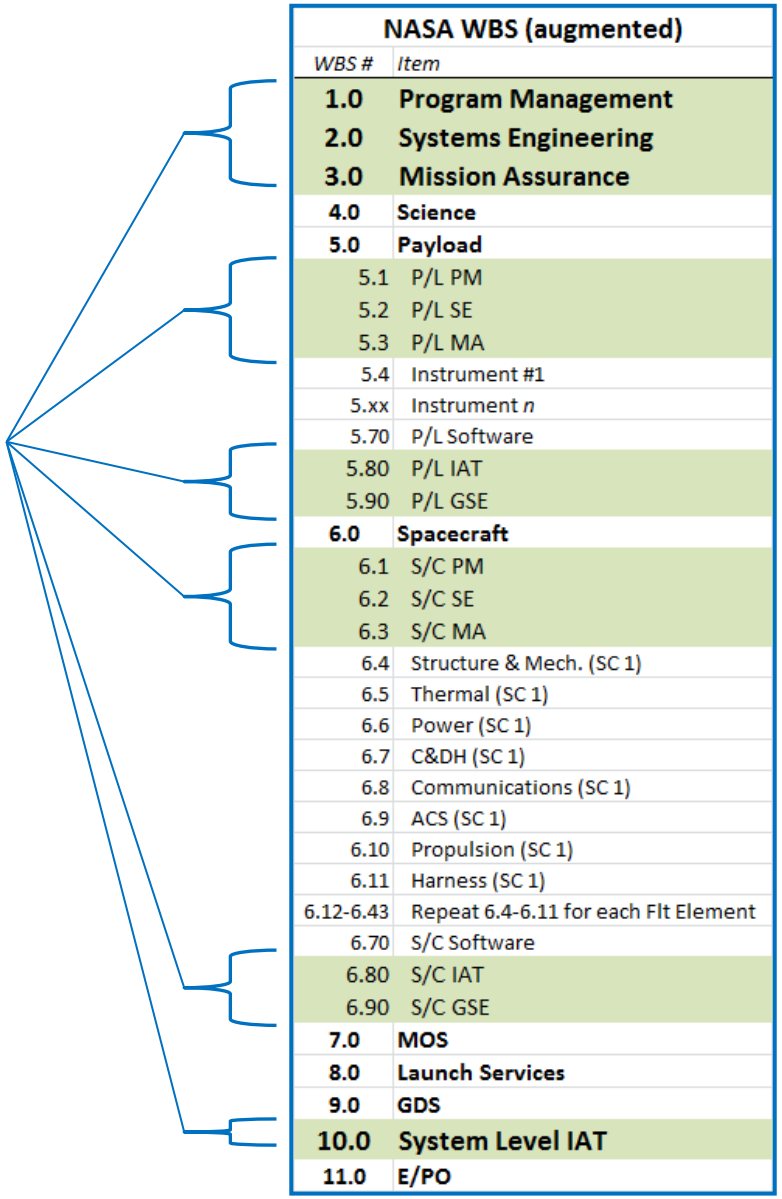
Objective & Approach

- **Objective**: ***Develop an improved estimating methodology to capture Management, Systems Engineering, Mission Assurance, and Integration & Test costs***
  - Explore alternatives to the "wrap factor" approach
  - **Cover robotic science spacecraft projects (unmanned)**
- Effort began with proof-of-concept rapid prototype development using an approach similar to what is used for the NASA Space Operations Cost Model (SOCM)
- 2nd Modeling effort explored three alternatives:
  - Standard regression approach
  - Constructive, SOCM-like approach (relies on expert judgment)
  - Statistical approach using Principal Component Analysis (PCA)

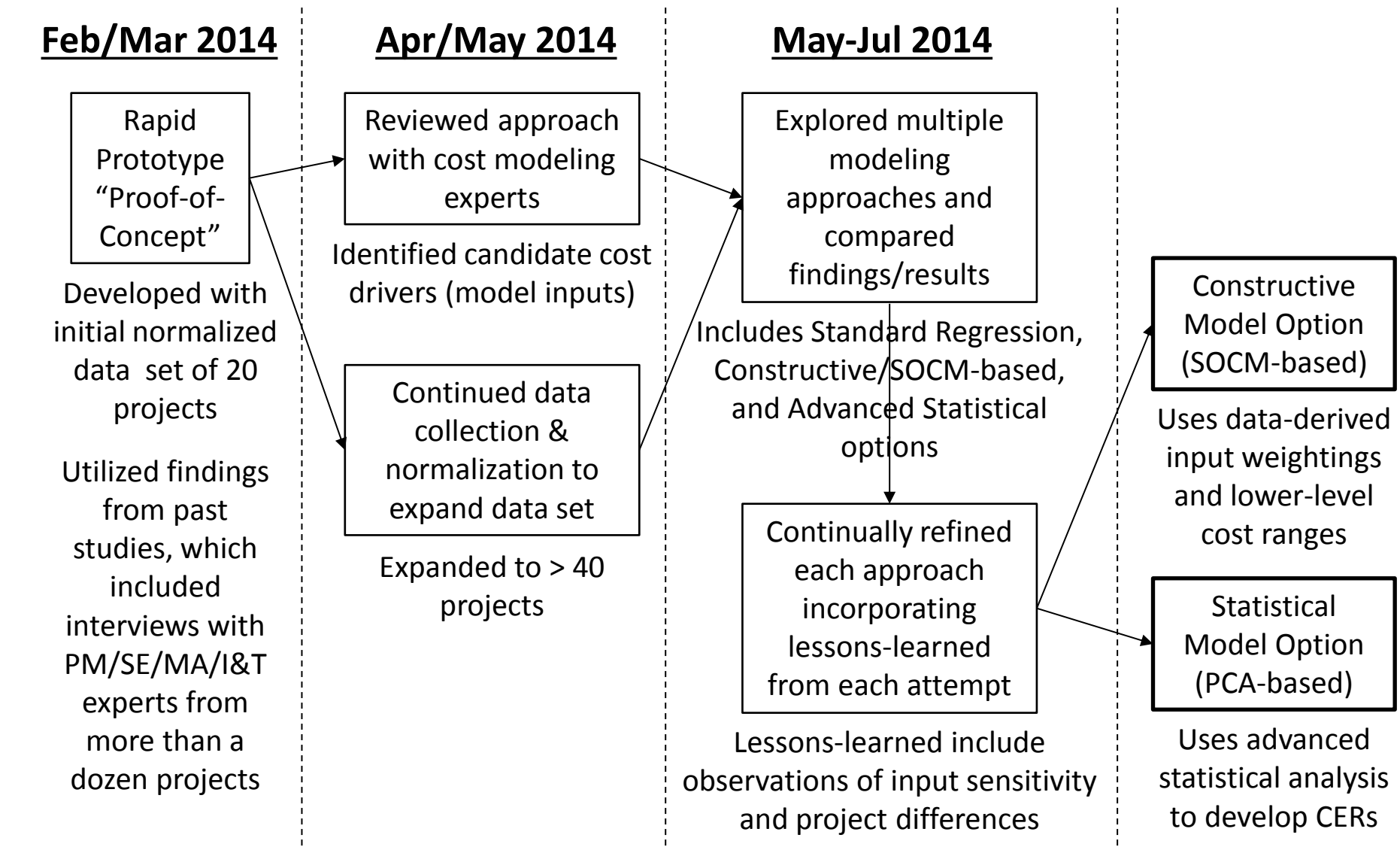
NASA WBS Elements Included

NASA WBS items included for this modeling effort



NASA WBS (augmented)	
WBS #	*Item*
1.0	**Program Management**
2.0	**Systems Engineering**
3.0	**Mission Assurance**
4.0	**Science**
5.0	**Payload**
5.1	P/L PM
5.2	P/L SE
5.3	P/L MA
5.4	Instrument #1
5.xx	Instrument *n*
5.70	P/L Software
5.80	P/L IAT
5.90	P/L GSE
6.0	**Spacecraft**
6.1	S/C PM
6.2	S/C SE
6.3	S/C MA
6.4	Structure & Mech. (SC 1)
6.5	Thermal (SC 1)
6.6	Power (SC 1)
6.7	C&DH (SC 1)
6.8	Communications (SC 1)
6.9	ACS (SC 1)
6.10	Propulsion (SC 1)
6.11	Harness (SC 1)
6.12-6.43	Repeat 6.4-6.11 for each Flt Element
6.70	S/C Software
6.80	S/C IAT
6.90	S/C GSE
7.0	**MOS**
8.0	**Launch Services**
9.0	**GDS**
10.0	**System Level IAT**
11.0	**E/PO**

Study Timeline/Schedule



Rapid Prototype Inputs

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- **Individual input weightings are assigned for each WBS element (PM/SE/MA/I&T) in each phase (Design/Fab/I&T/Launch Ops)**

Inputs Used for Rapid Prototype

			1	2	3	4	5
Program-matics	1a	NASA PROGRAM	EV, Other	Explorer	Discovery	New Frontiers	Flagship
	1b	MISSION RISK CLASS	Class D	Class C	Class B		Class A
	1c	MISSION TARGET/TYPE	Earth Orbiting or Lunar	Mercury, Venus, Mars	Small Bodies	Outer Planets	Planetary Lander or Sample Return
Lead Type	2a	LEAD ORGANIZATION TYPE	Univ	Govt	APL/JPL/SwRI	Industry	Mix/Int'l
	2b	FLIGHT SYSTEM ORGANIZATION TYPE	Univ	Govt	APL/JPL/SwRI	Industry	Mix/Int'l
	2c	PAYLOAD ORGANIZATION TYPE	Univ	Govt	APL/JPL/SwRI	Industry	Mix/Int'l
Lead Exp	3a	LEAD ORG EXPERIENCE	Extensive		Nominal		Minimal
	3b	FLIGHT SYSTEM LEAD ORG EXPERIENCE	Extensive		Nominal		Minimal
	3c	PAYLOAD LEAD ORG EXPERIENCE	Extensive		Nominal		Minimal
	4	INHOUSE SCOPE	All Flight Elements Inhouse	Most Flight Elements Inhouse	System contractor for Flight HW	Multiple (2+) major system contractors	Multiple major developers including Gov+Ind
	5	INTERNATIONAL PARTICIPATION	No Int'l HW or CoI's	No Int'l HW; Some Int'l CoIs	Minimal Int'l HW; Some Int'l CoIs	$2-10M of Int'l HW + Int'l CoI's	Sign Int'l HW + Int'l CoI's
FltSys Size/Cplx	6a	FLIGHT SYSTEM MASS	<200kg	200-400kg	400-600kg	600-1000kg	>1000kg
	6b	FLIGHT SYSTEM POWER	<250W	250-500W	500-700W	700-1000W	>1000W
	6c	FLIGHT SYSTEM HERITAGE&TRL	No TRL<7	1-2 TRL<7 items	3-4 TRL<7 items	Several TRL<7 items	Significant ATD for key elements
Pyld Size/Cplx	7a	PAYLOAD MASS	<50kg	50-100kg	100-150kg	150-300kg	>300kg
	7b	PAYLOAD POWER	<50W	50-100W	100-300W	300-500W	>500W
	7c	PAYLOAD HERITAGE&TRL	No TRL<7	1-2 TRL<7 items	3-4 TRL<7 items	Several TRL<7 items	Significant ATD for key elements

Add'l Input Candidates

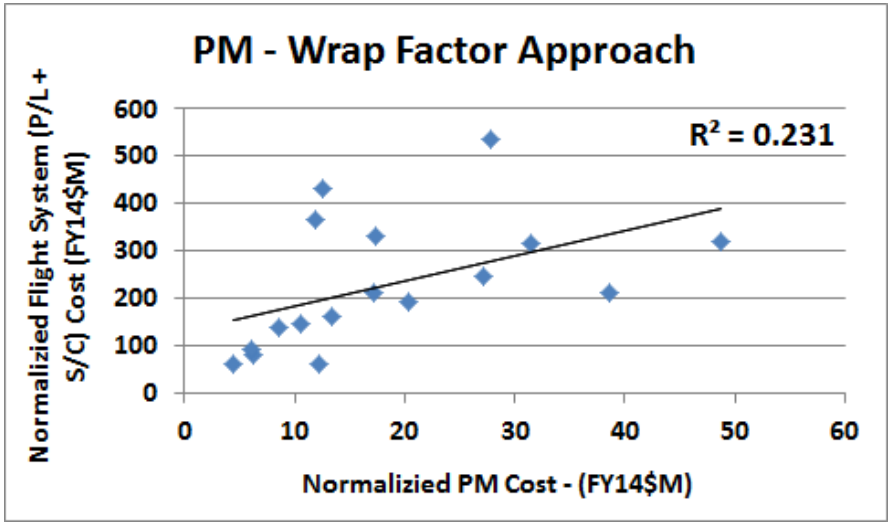
Management: # of Major External I/Fs, S/C Contractor Cost, S/C In-House Cost, Degree of Off-site Oversight, Scope of Identified Risks

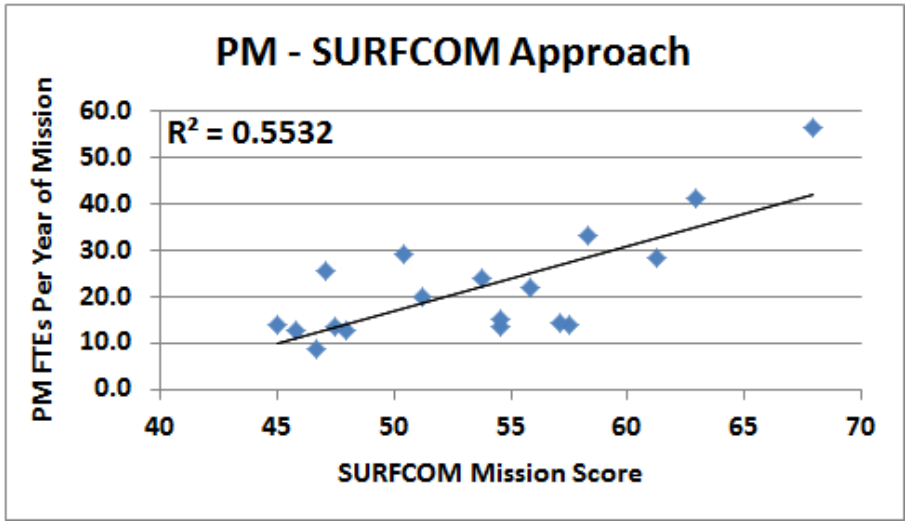
Sys Engrng: # of Reqts, Simulation/Test Scope, Contingencies/Margins, Redundancy, Prototyping, Funded Schedule Margin, Unfunded Schedule Slack

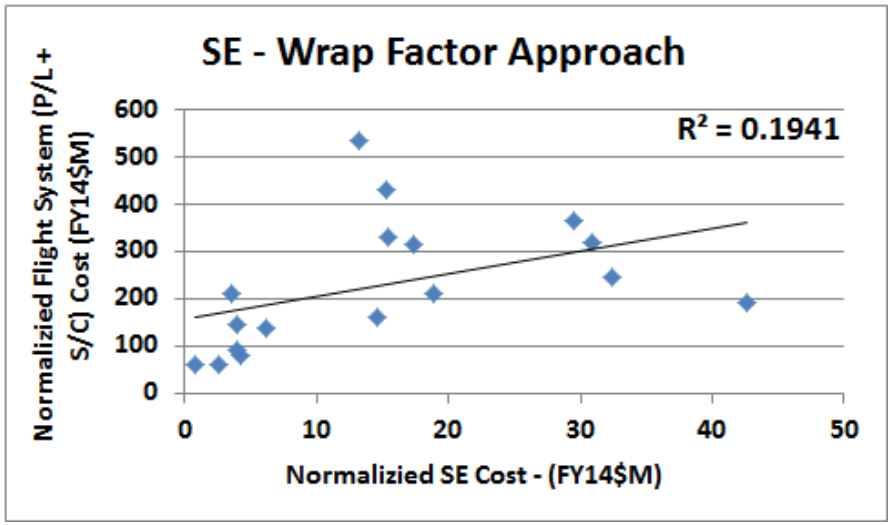
Mission Assurance: Parts Quality, Redundancy, Sparing

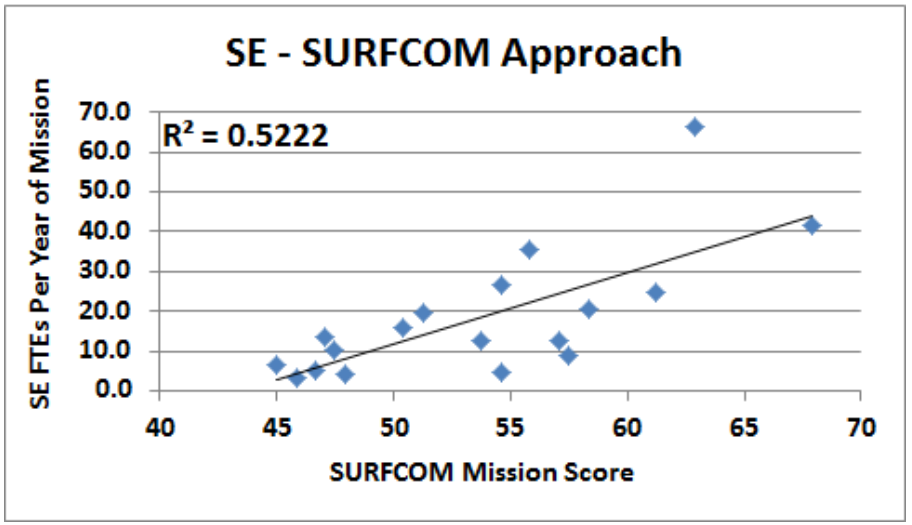
I&T: # of Flight Elements, Prototyping, Facility Reqts, GSE, Spares, I&T Schedule Margin/Slack

Rapid Prototype Comparison to Wrap Factors, 1 of 2









SURFCOM = Support Function Cost Model

Rapid Prototype Comparison to Wrap Factors, 2 of 2

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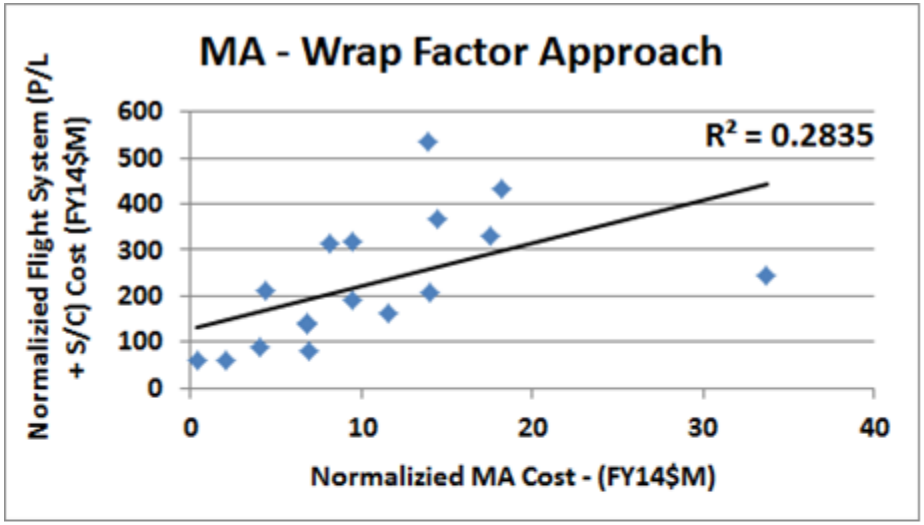
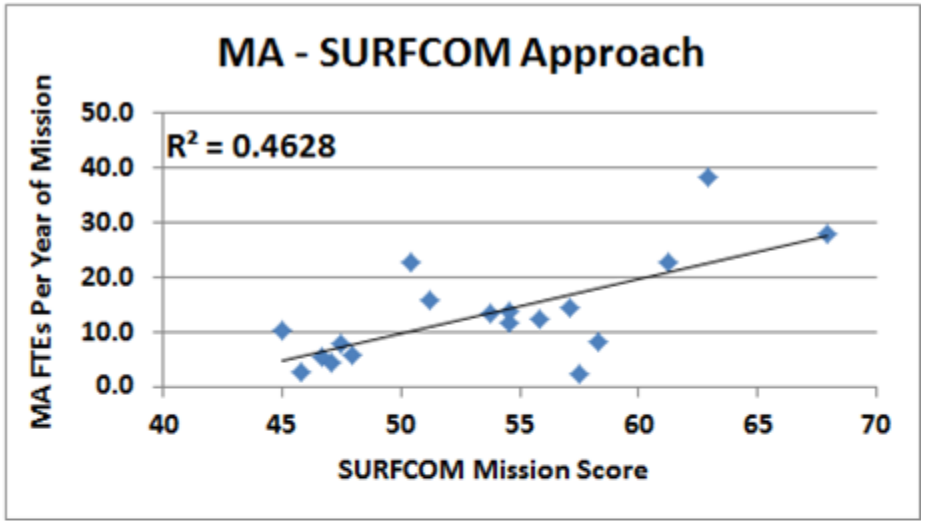
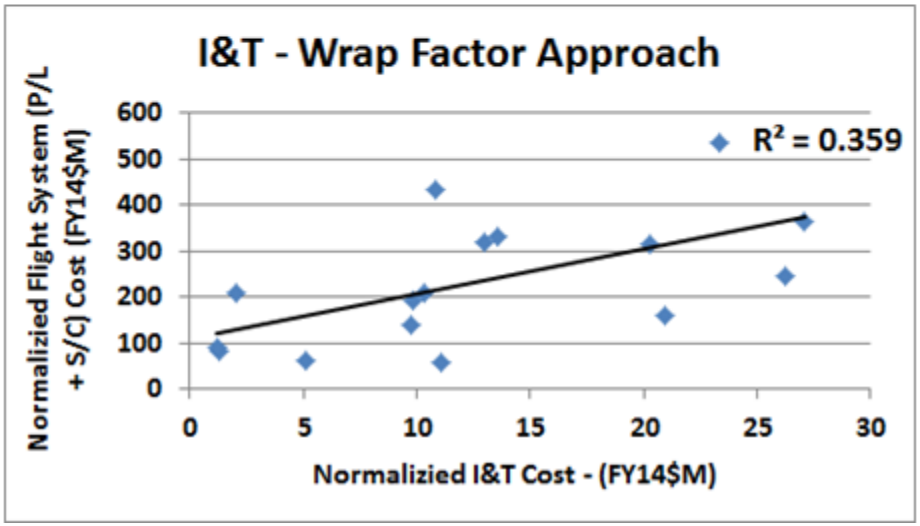
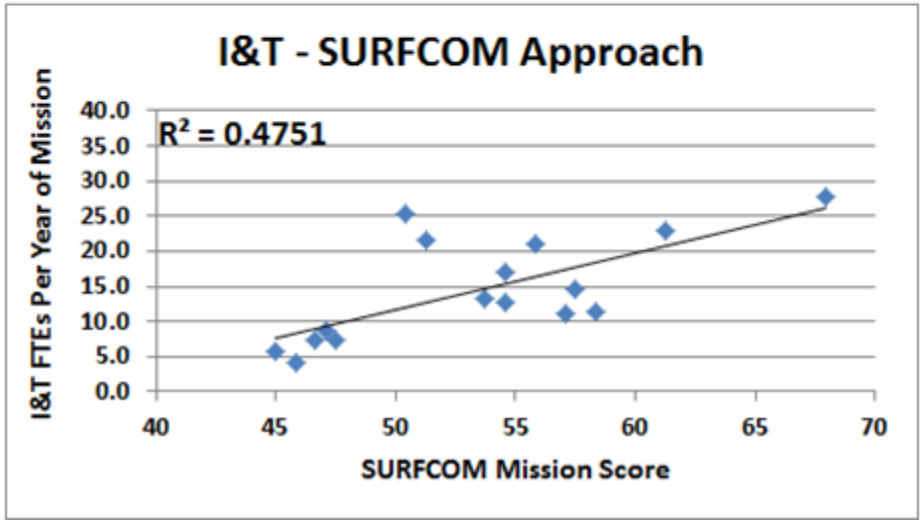








SURFCOM = Support Function Cost Model

Model Development
A fork in the road

Although the prototype approach showed improvement over using wrap factors, it lacked the traceability to the data that comes with a more math/statistics-based approach.

Although separate paths were explored, there was significant "cheating", where progress down one path was gained from a successful/failed attempt down a different path

<u>"Common-Sense" Path</u>

Explored optimization of a constructive SOCM-type approach

<u>Math/Statistics Path</u>

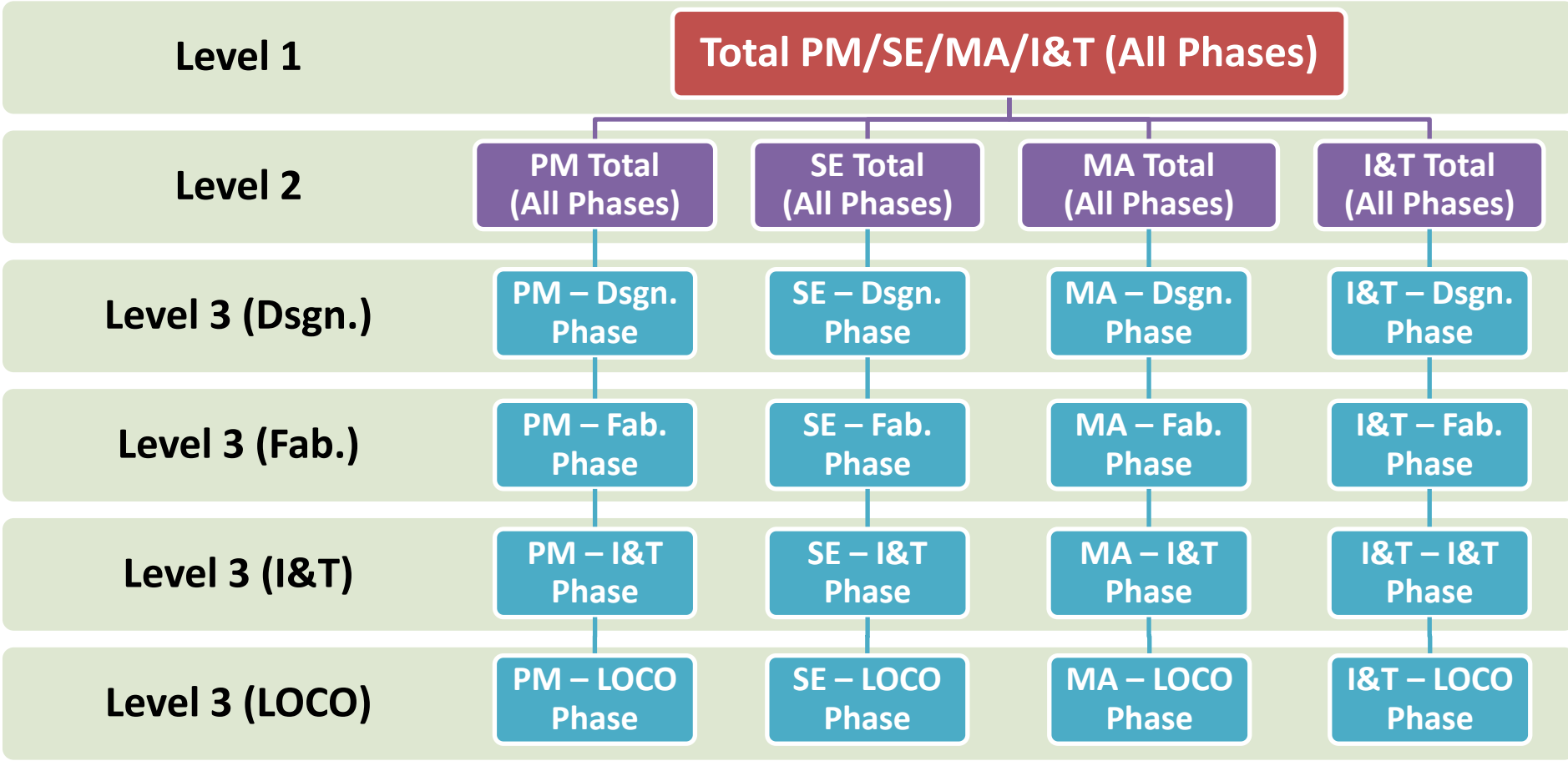
Explored standard regression and other advanced statistical approaches

Expanded Model Data Set

- Before going further with any modeling attempts, additional data was analyzed and normalized to provide an expanded data set
- The data set used for the initial prototype effort was more than doubled
- The process used for normalizing the data was applied to the latest launch CADRe (described in a separate presentation)

		MISSION	Launch Date	Lead Org PM	Lead Org Flt Sys	NASA Program
Rapid Prototype Projects	1	TDRSS K-L	1/23/14	GSFC	Boeing	Space Comm
	2	MAVEN	11/18/13	GSFC	LMA	Planetary
	3	LADEE	9/6/13	GSFC	ARC	Planetary
	4	IRIS	6/27/13	GSFC	LMMS	Astrophysics/SMEX
	5	Van Allen Probes	8/30/12	GSFC	APL	Heliophysics/LWS
	6	NuSTAR	6/13/12	JPL	OSC	Astrophysics/Explorer
	7	MSL	11/26/11	JPL	JPL/LMA	Planetary/Mars Expl
	8	GRAIL	9/10/11	JPL	LMA	Planetary/Discovery
	9	Juno	8/5/11	JPL	LMA	Planetary/New Frontiers
	10	Glory	3/4/11	GSFC	OSC/Swales	Earth Sciences
	11	GOES (-P)	3/4/10	GSFC/NOAA	Boeing/SGT	Earth Sciences
	12	SDO	2/11/10	GSFC	GSFC	Heliophysics
	13	WISE	12/14/09	JPL	BATC	Astrophysics/Explorer
	14	LCROSS	6/18/09	ARC	NG	Planetary/Discovery
	15	LRO	6/18/09	GSFC	GSFC	Planetary
	16	KEPLER	3/6/09	JPL	BATC	Astrophysics/Discovery
	17	OCO	2/24/09	JPL	OSC	Earth Science
	18	IBEX	10/19/08	SwRI	OSC	Astrophysics/Explorer
	19	DAWN	9/27/07	JPL	OSC/JPL	Planetary/Discovery
	20	Phoenix	8/4/07	JPL	LMA	Planetary
Added Projects for Expanded Set	21	AIM	4/25/07	LASP	OSC	Heliophysics
	22	THEMIS	2/17/07	UCB	Swales	Astrophysics/Explorer
	23	STEREO	10/26/06	GSFC	APL	Heliophysics
	24	CLOUDSAT	4/28/06	GSFC	BATC	Earth Sciences
	25	NEW HORIZONS	1/19/06	APL	APL	Planetary/New Frontiers
	26	MRO	8/12/05	JPL	LMA	Planetary/Mars Expl
	27	DEEP IMPACT	1/12/05	JPL	BATC	Planetary/Discovery
	28	Swift	11/20/04	GSFC	Spectrum Astro	Astrophysics/Explorer
	29	MESSENGER	8/3/04	APL	APL	Planetary/Discovery
	30	Spitzer	8/25/03	JPL	LMA	Astrophysics
	31	MER	6/10/03	JPL	JPL	Planetary/Mars Expl
	32	GALEX	4/28/03	JPL	OSC	Astrophysics/Explorer
	33	RHESSI	2/5/02	UCB	Spectrum Astro	Heliophysics
	34	TIMED	12/7/01	APL	APL	Earth Sciences
	35	GENESIS	8/8/01	JPL	LMA	Planetary/Discovery
	36	Mars Odyssey	7/7/01	JPL	LMA	Planetary/Mars Expl
	37	WMAP	6/30/01	GSFC	GSFC	Astrophysics/Explorer
	38	WIRE	3/5/99	GSFC	GSFC	Astrophysics/Explorer
	39	TRACE	4/2/98	GSFC	GSFC	Astrophysics/Explorer
	40	Cassini	10/15/97	JPL	JPL	Planetary/Outer Planets
	41	Mars Global Surveyor	11/7/96	JPL	LMA	Planetary/Mars Expl
	42	NEAR	2/17/96	APL	APL	Planetary/Discovery

Data Levels



Design (Dsgn.) Phase is defined as the period between start of **Phase B** and **CDR**
Fabrication (Fab.) Phase is defined as the period between **CDR** and **SIR**
Integration & Test (I&T) Phase is defined as the period between **SIR** and **Ship** (to launch site)
Launch Ops. & Check Out (LOCO) Phase is defined as the period between **Ship** and **End of On-Orbit C/O**

Model Development
Standard Regression Approach

- A standard regression analysis was performed using Excel to give a baseline for the analysis.
  - Best fits were mostly linear
  - Outliers were present but were not removed
  - R^2 values ranged from approximately 0.2 to 0.8
- The relationships obtained from this analysis were used to estimate the observations in the data set at all 3 levels.
  - The percent difference was approximately the same across all the levels at -60% to 350%

Standard Regression Approach Results

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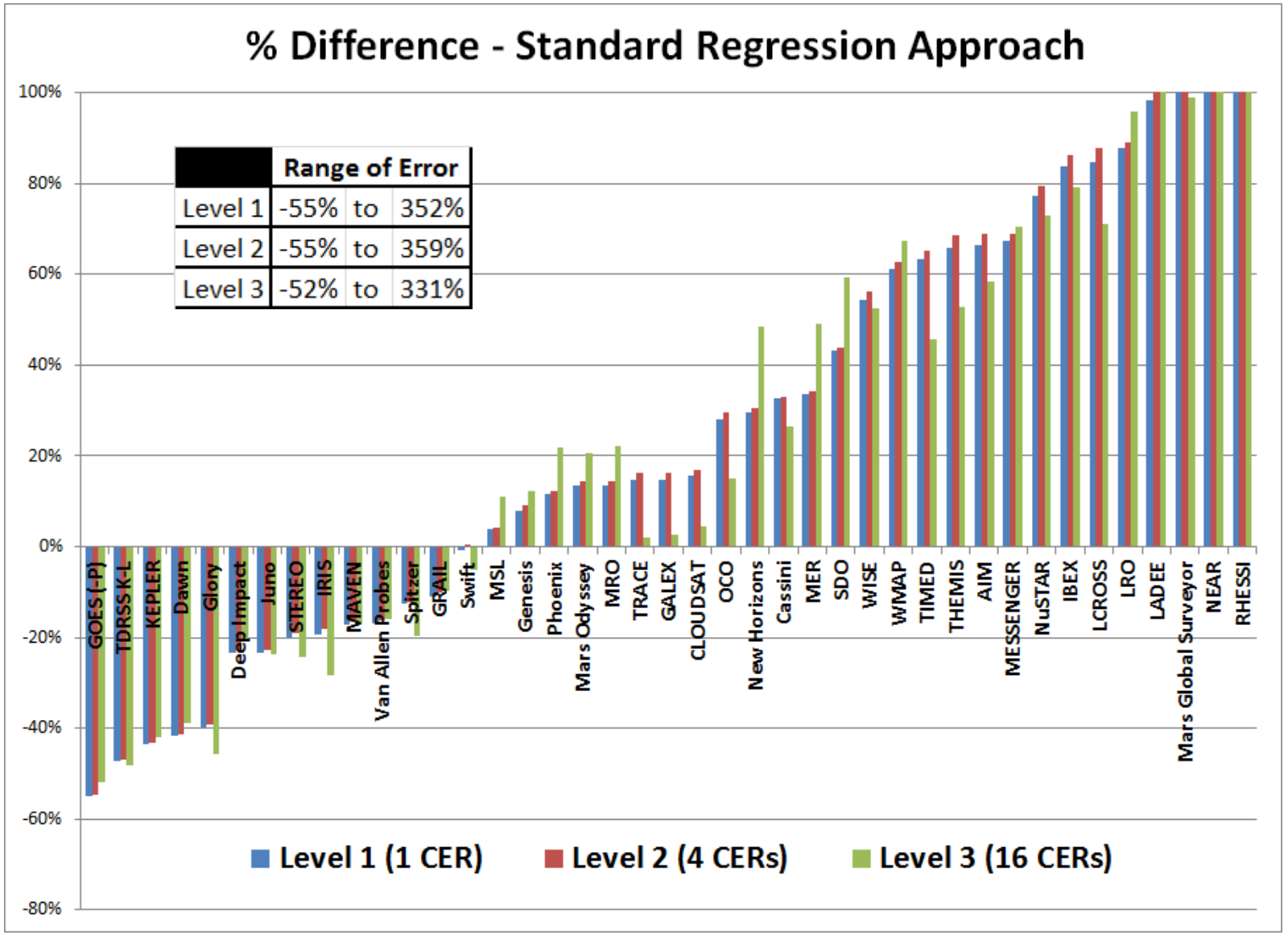

Model Development Constructive Approach

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1) Developed ranges for each item across each development phase using normalized data results

	DB LOW $K/mo DES	DB LOW $K/mo FAB	DB LOW $K/mo I&T	DB LOW $K/mo LOCO	DB HIGH $K/mo DES	DB HIGH $K/mo FAB	DB HIGH $K/mo I&T	DB HIGH $K/mo LOCO
PM	59.1	36.7	65.4	3.3	2,005	1,650	1,150	1,122
SE	25.0	13.3	13.2	0.2	3,358	2,525	2,248	2,768
MA	25.3	6.4	2.1	0.2	1,573	1,765	1,163	731
I&T	0.3	2.9	10.7	0.1	1,857	1,763	3,762	6,170

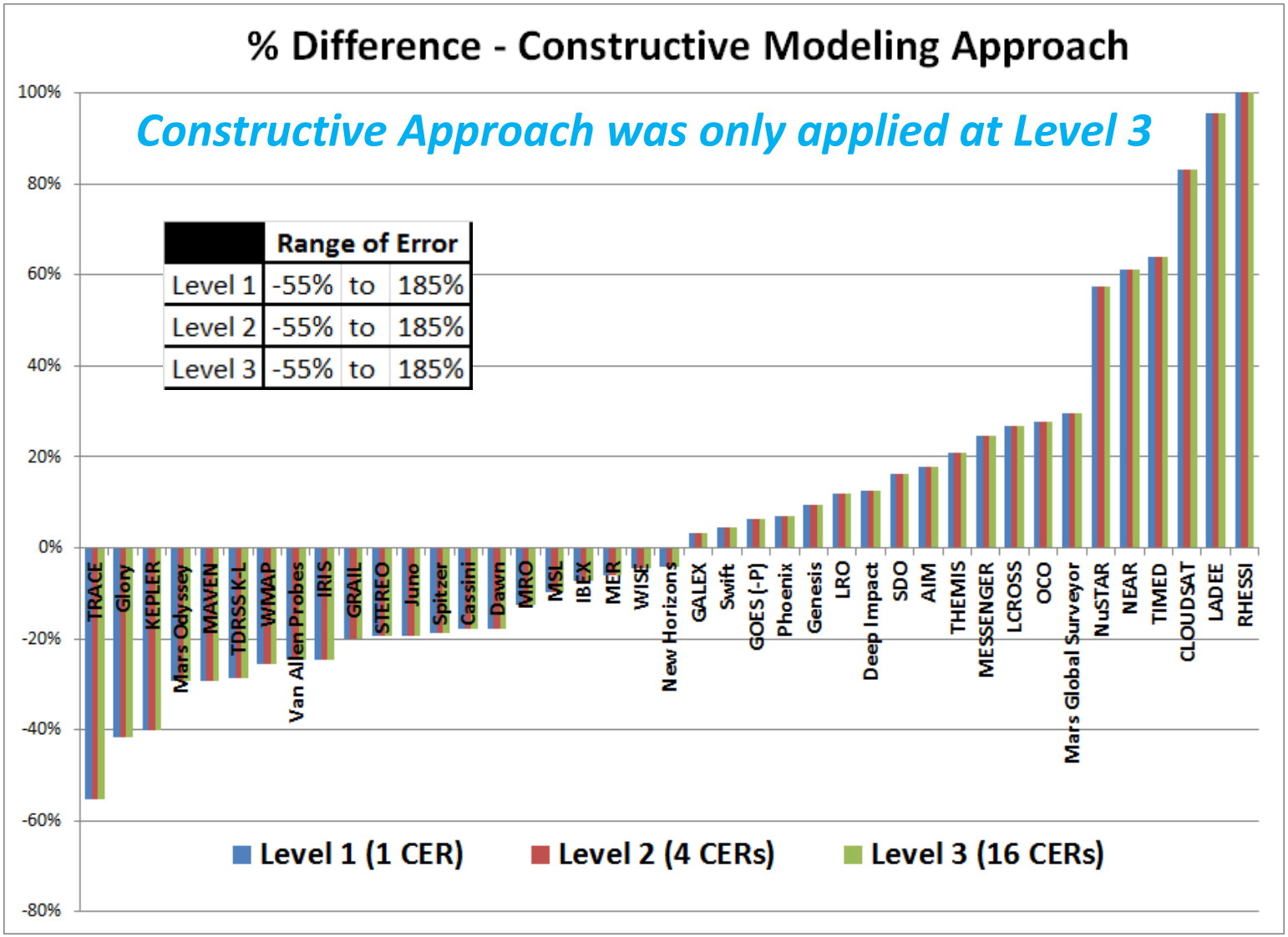
2) Assigned input weightings – this process used a combination of common-sense (using past studies and experience) and results from statistical analysis (= *cheating*)

Weightings												kg	W	W/kg					kg	W	W/kg				
Input #	DIRECTED or AO	MISSION RISK CLASS	MISSION DESTINATION	FLIGHT SYSTEM TYPE	MULTIPLE FLIGHT SYSTEMS ?	LEAD ORGANIZATION	FLIGHT SYSTEM ORGANIZATION	PAYLOAD ORG.	LEAD ORGANIZATION EXPERIENCE	FLIGHT SYSTEM LEAD ORG. EXPERIENCE	PAYLOAD LEAD ORG. EXPERIENCE	FLIGHT SYSTEM MASS	FLIGHT SYSTEM POWER	FLIGHT SYSTEM POWER/ MASS RATIO	NUMBER OF SPACECRAFT	FLIGHT SYSTEM HERITAGE & TRL	PARTS RATING	# OF KEY SPACECRAFT CONTRACTORS	PAYLOAD MASS	PAYLOAD POWER	PAYLOAD POWER/ MASS RATIO	# OF PAYLOAD ELEMENTS	# OF KEY PAYLOAD CONTRACTORS	IN-HOUSE SCOPE	INTERNATIONAL PARTICIPATION (HW)
1	0.5	0.35	0.3	0.1	0	0.05	0.05		0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
2	1.2	0.5	0.6	0.3	1	0.1	0.1		0.4	0.4	0.4	1	1	1	1	1	1	1	1	1	1	1	1	1	0.4	1
3		0.75	0.6	0.4		0.6	0.6		0.6	0.6	0.6														0.6	
4		1.8	0.7	0.6		1.2	1.3		0.8	0.8	0.8														0.8	
5			0.9	0.8		1.8	1.2		1	1	1														1	
6			1.747	1.5																						
7			2																							

3) Input weightings include weightings for each input option and for each input to a specific WBS/phase

Correlations		DIRECTED or AO	MISSION RISK CLASS	MISSION DESTINATION	FLIGHT SYSTEM TYPE	MULTIPLE FLIGHT SYSTEMS ?	LEAD ORGANIZATION	FLIGHT SYSTEM ORGANIZATION	PAYLOAD ORG.	LEAD ORGANIZATION EXPERIENCE	FLIGHT SYSTEM LEAD ORG. EXPERIENCE	PAYLOAD LEAD ORG. EXPERIENCE	FLIGHT SYSTEM MASS	FLIGHT SYSTEM POWER	FLIGHT SYSTEM POWER/ MASS RATIO	NUMBER OF SPACECRAFT	FLIGHT SYSTEM HERITAGE & TRL	PARTS RATING	# OF KEY SPACECRAFT CONTRACTORS	PAYLOAD MASS	PAYLOAD POWER	PAYLOAD POWER/ MASS RATIO	# OF PAYLOAD ELEMENTS	# OF KEY PAYLOAD CONTRACTORS	IN-HOUSE SCOPE	INTERNATIONAL PARTICIPATION (HW)
PM	DES	0	1.05	0.2625	0	0.525	0	0.525	0.7875	0.7875	0.525	1.3125	0.7875	1.3125	0	0	0	1.05	0	1.05	1.3125	0	0	0	0	0
	FAB	0	0.525	0.2625	0	0.525	0	0.7875	0.525	0.7875	0.525	0.7875	0.7875	1.05	0.525	0	0	1.05	0.525	0.525	0.525	0	0	0	0	0
	I&T	0	0	0.2625	0	0.525	0	0.7875	0	0	0	0	0	0.7875	0.525	0	0	0.7875	0.525	0	0	0	0	0	0	0
	LOCO	0	0	0.525	0.525	0.525	0.525	0.525	0	0	0	0.525	1.05	0.525	0	0	0	0.525	1.05	0	0	0.525	0	0	0	0
SE	DES	0.4	0.8	0.2	0	0.4	0	0.6	0.6	0.6	0.4	1	0.4	0.6	0	0	0	0.6	0	0	0.6	0.4	0	0	0	0
	FAB	0.4	0.6	0.6	0.8	0.4	0.64	0.8	0.4	0.4	0	0.4	0.8	0.4	0	0	0	0.8	0.6	0	0	0.4	0	0	0	0
	I&T	0	0.4	0.4	0.8	0.4	0.64	0.6	0	0.4	0	0	0.8	0	0	0	0	0.8	0.6	0	0	0	0	0	0	0
	LOCO	0	0.4	0.4	1	0.4	0.8	0.6	0	0.4	0	0	1.2	0.4	0	0	0	0.8	0.6	0	0.4	0.8	0	0	0	0
MA	DES	0	1.25	0.5	0	0.5	0	0.5	0.5	0	0	1	1	0.75	0	0	0	1.25	0	0.5	0.75	0	0	0	0.5	0
	FAB	0	0.75	1	0	0.5	0	0.5	0	0	0	0.75	1.5	0.5	0	0	0.5	1.5	0.5	0	0.5	0	0.75	0.5	0.5	0
	I&T	0	0	0.75	0	0.5	0	0.5	0	0	0	0	0.5	0.5	0	0	0.5	1	0	0	0	0	0	0.5	0	0
	LOCO	0	0.5	0.5	0	0.5	0	0.5	0	0	0	0	0.5	0.75	0.5	0	0.5	0.75	0.5	0	0	0	0	0	0	0
I&T	DES	0	0.75	0.25	0	0.5	0	0	0.5	0.5	0.5	1.25	0.5	0.75	0	0	0	0.75	0	0.75	1.25	0	0	0	0	0
	FAB	0	0	0.5	0.5	0.5	0.5	0.75	0	0.5	0	0.5	1.25	0.5	0	0	0	1	0.5	0.75	1	0.5	0.5	0	0	0
	I&T	0	0	0.75	1	0.5	1	0.5	0	0	0	0	1.5	0	0	0	0	0.75	0.75	0	0.5	0.75	0.75	0	0	0
	LOCO	0	0	0.5	0.75	0.5	0.75	0	0	0	0	0	1.5	0	0	0	0	0.5	0.75	0	1	1	0.75	0	0	0

Constructive Approach Results

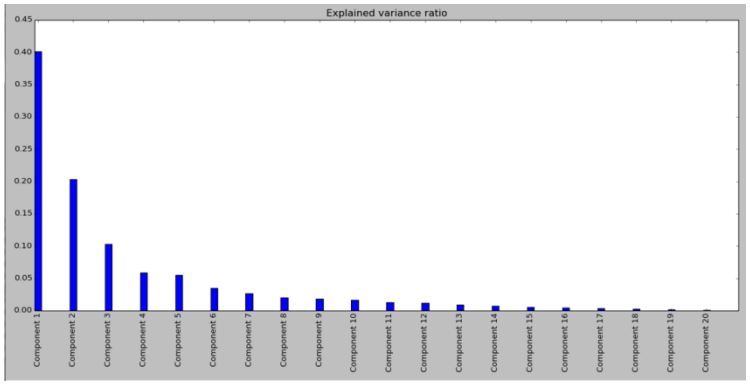


Model Development
Principle Component Analysis Approach

1) A correlation matrix was generated to get a sense of the of the dependency between variables.

   - Several of the variables appeared to be correlated, making PCA an attractive method to apply to the data set.

	LN $k-FY14 Per Month	LN DIRECTED or AO	LN MISSION RISK CLASS	LN MISSION DESTINATION	LN FLIGHT SYSTEM TYPE	LN LEAD ORGANIZATION	LN FLIGHT SYSTEM ORGANIZATION	LN PAYLOAD ORG.	LN FLIGHT SYSTEM LEAD ORG. EXPERIENCE	LN PAYLOAD LEAD ORG. EXPERIENCE	LN FLIGHT SYSTEM MASS	LN FLIGHT SYSTEM POWER	LN FLIGHT SYSTEM HERITAGE & TRL	LN PARTS RATING	LN # OF KEY SPACECRAFT CONTRACTORS	LN PAYLOAD MASS	LN PAYLOAD POWER	LN # OF PAYLOAD ELEMENTS	LN # OF KEY PAYLOAD CONTRACTORS	LN IN-HOUSE SCOPE	LN INTERNATIONAL PARTICIPATION (HW)
LN $k-FY14 Per Month	1																				
LN DIRECTED or AO	0.25	1																			
LN MISSION RISK CLASS	-0.6	-0.5	1																		
LN MISSION DESTINATION	0.55	-0	-0.2	1																	
LN FLIGHT SYSTEM TYPE	0.16	0.07	0.09	0.37	1																
LN LEAD ORGANIZATION	0.66	0.29	-0.4	0.22	0.13	1															
LN FLIGHT SYSTEM ORGANIZATION	0.34	-0	0.06	0.09	0.12	0.27	1														
LN PAYLOAD ORG.	0.39	0.14	-0.2	-0	0.05	0.52	0.39	1													
LN FLIGHT SYSTEM LEAD ORG. EXPERIENCE	0.21	0.14	-0.1	0	-0.2	0.3	0.31	0.12	1												
LN PAYLOAD LEAD ORG. EXPERIENCE	0.63	0.2	-0.5	0.34	-0.1	0.26	0.33	0.15	0.49	1											
LN FLIGHT SYSTEM MASS	0.74	0.38	-0.5	0.48	0.11	0.55	0.07	0.3	0.07	0.48	1										
LN FLIGHT SYSTEM POWER	0.6	0.21	-0.4	0.06	-0.1	0.57	0.08	0.3	0.06	0.32	0.72	1									
LN FLIGHT SYSTEM HERITAGE & TRL	0.02	-0.1	0.01	-0	-0.2	0.02	0.3	0.02	0.44	0.38	-0.1	-0.2	1								
LN PARTS RATING	0.76	0.19	-0.6	0.54	0.22	0.52	-0	0.34	0.03	0.55	0.71	0.58	-0.2	1							
LN # OF KEY SPACECRAFT CONTRACTORS	0.43	0.04	-0.1	0.46	0.27	0.16	0.18	0.3	-0.2	0.06	0.38	0.19	-0.1	0.33	1						
LN PAYLOAD MASS	0.27	0.3	-0.3	-0.1	-0.1	0.44	0.11	0	0.43	0.2	0.28	0.31	0.14	0.19	-0.4	1					
LN PAYLOAD POWER	0.39	0.42	-0.4	-0.1	-0.1	0.46	0.2	0.28	0.36	0.41	0.54	0.55	0.12	0.34	-0	0.7	1				
LN # OF PAYLOAD ELEMENTS	0.08	0.06	-0.1	0.31	0.12	-0.4	-0.3	-0.2	-0.2	0.15	0.18	-0.2	-0.2	0.12	0.23	-0.4	-0.2	1			
LN # OF KEY PAYLOAD CONTRACTORS	-0.1	-0.1	-0.1	0.12	-0.1	-0.2	-0.3	-0.2	-0.2	-0.2	-0	-0.1	-0.3	-0.1	-0.1	-0.1	-0.3	0.58	1		
LN IN-HOUSE SCOPE	0.34	0.18	-0.3	0.33	0.16	0.1	-0.3	0.03	0.03	0.3	0.49	0.16	-0.1	0.47	0.34	-0.1	0.08	0.47	0.08	1	
LN INTERNATIONAL PARTICIPATION (HW)	-0	0.15	-0.1	-0.2	-0.1	0.13	-0	0.12	0.23	-0.1	-0.1	0.09	-0.2	-0.1	0.03	-0	0.03	-0.2	-0.3	-0.1	1

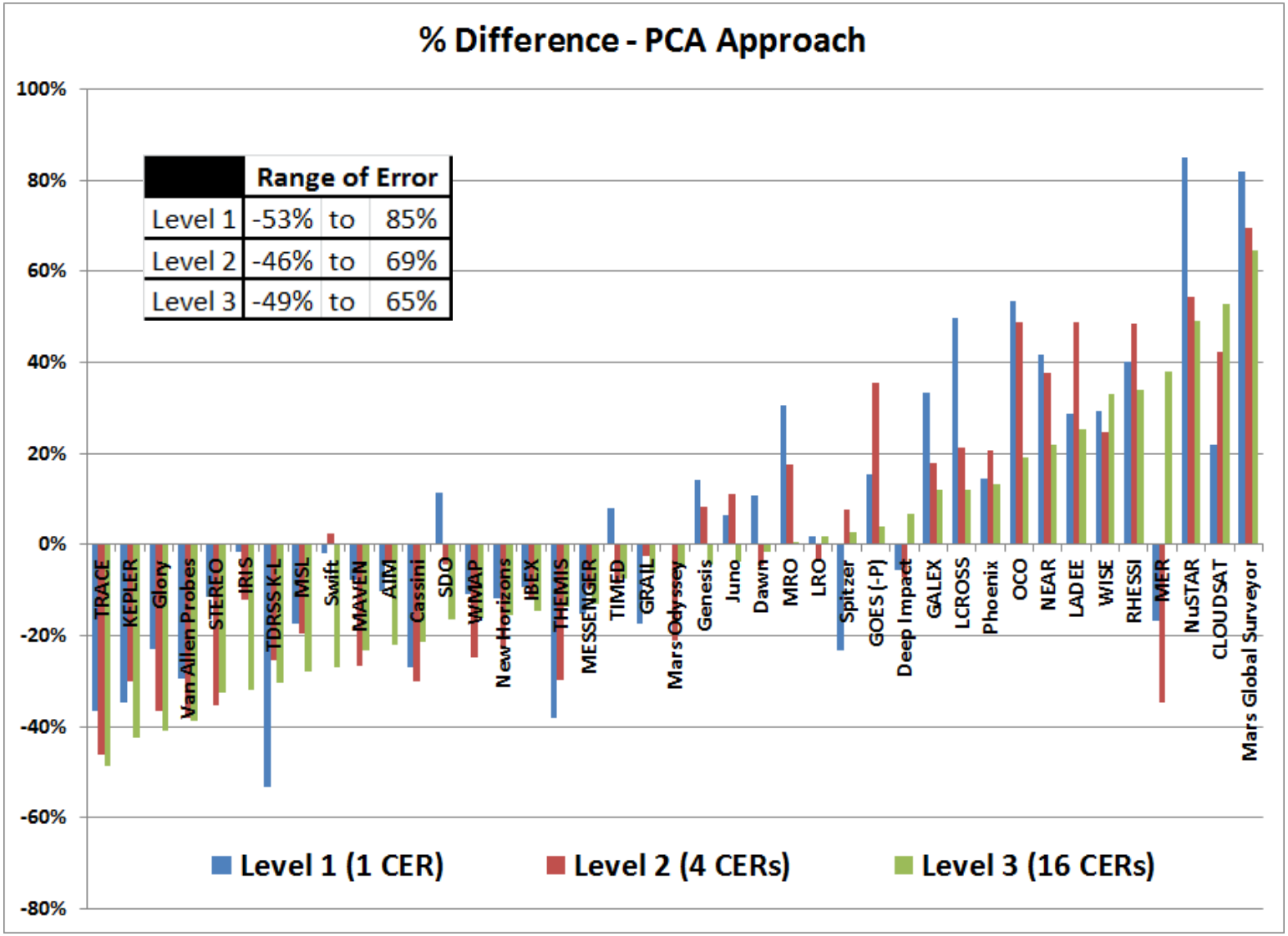


2) The principal components were determined using an algorithm developed in Python.

   - The first 6 principal components which account for 85% of variance in the data set were selected and used to determine which of the 20 variables were most likely related to cost.

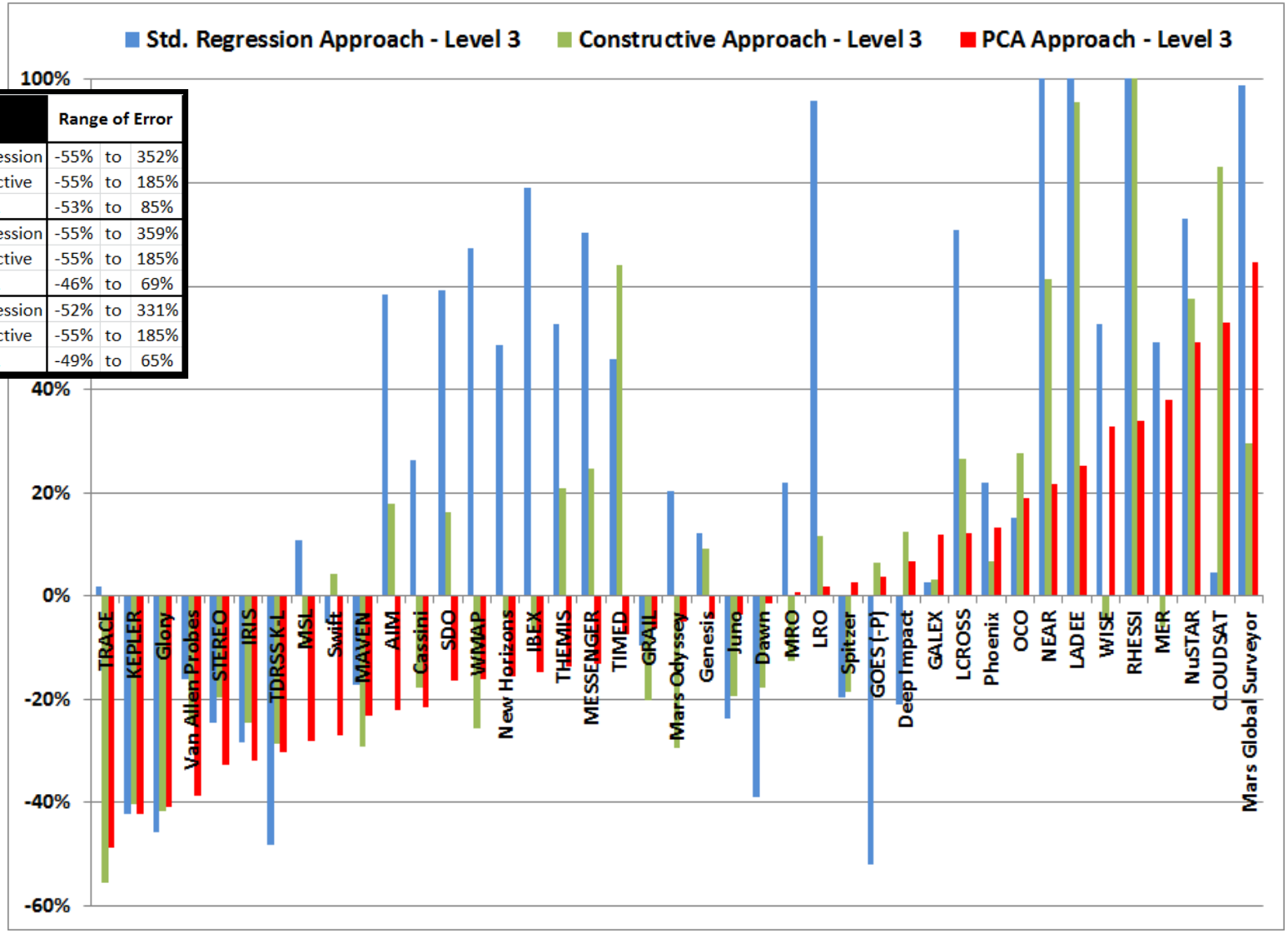
3) For each of the 21 data sets examined, 4 subsets of the 20 variables were run through a multiple regression routine to determine the new cost estimating relationships.

Principle Component Analysis Approach Results



Modeling Method Performance Comparisons

		Range of Error		
Level 1	Std. Regression	-55%	to	352%
	Constructive	-55%	to	185%
	PCA	-53%	to	85%
Level 2	Std. Regression	-55%	to	359%
	Constructive	-55%	to	185%
	PCA	-46%	to	69%
Level 3	Std. Regression	-52%	to	331%
	Constructive	-55%	to	185%
	PCA	-49%	to	65%



Results

TBD

Findings and Next Steps

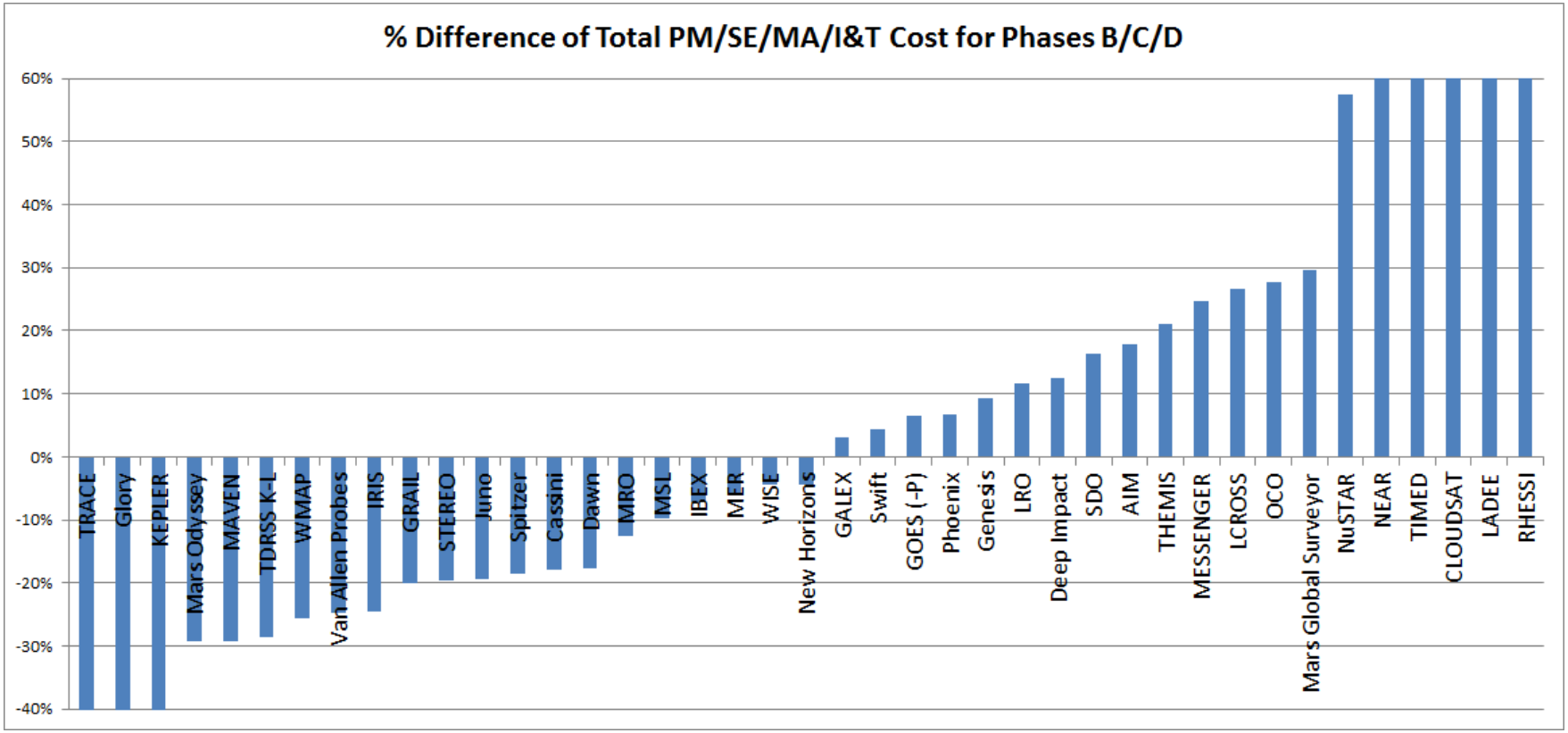
- Findings
  - Each of the modeling approaches developed provides an improvement over the wrap factor approach. The PCA approach provides the best results at levels 1, 2 and 3
    - The Level3 constructive approach range of errors is between -50% - 185%
    - The Level 3 PCA approach range of errors is between -50% - 65%

- Next Steps
  - Consider eliminating extreme outliers
  - Try to improve the normalized data set by:
    - Increasing the number of normalized observations
    - Improve support function lower level allocations in the normalized data
  - Explore non-linear statistical techniques
  - Subject Matter Expert review of inputs and relationships

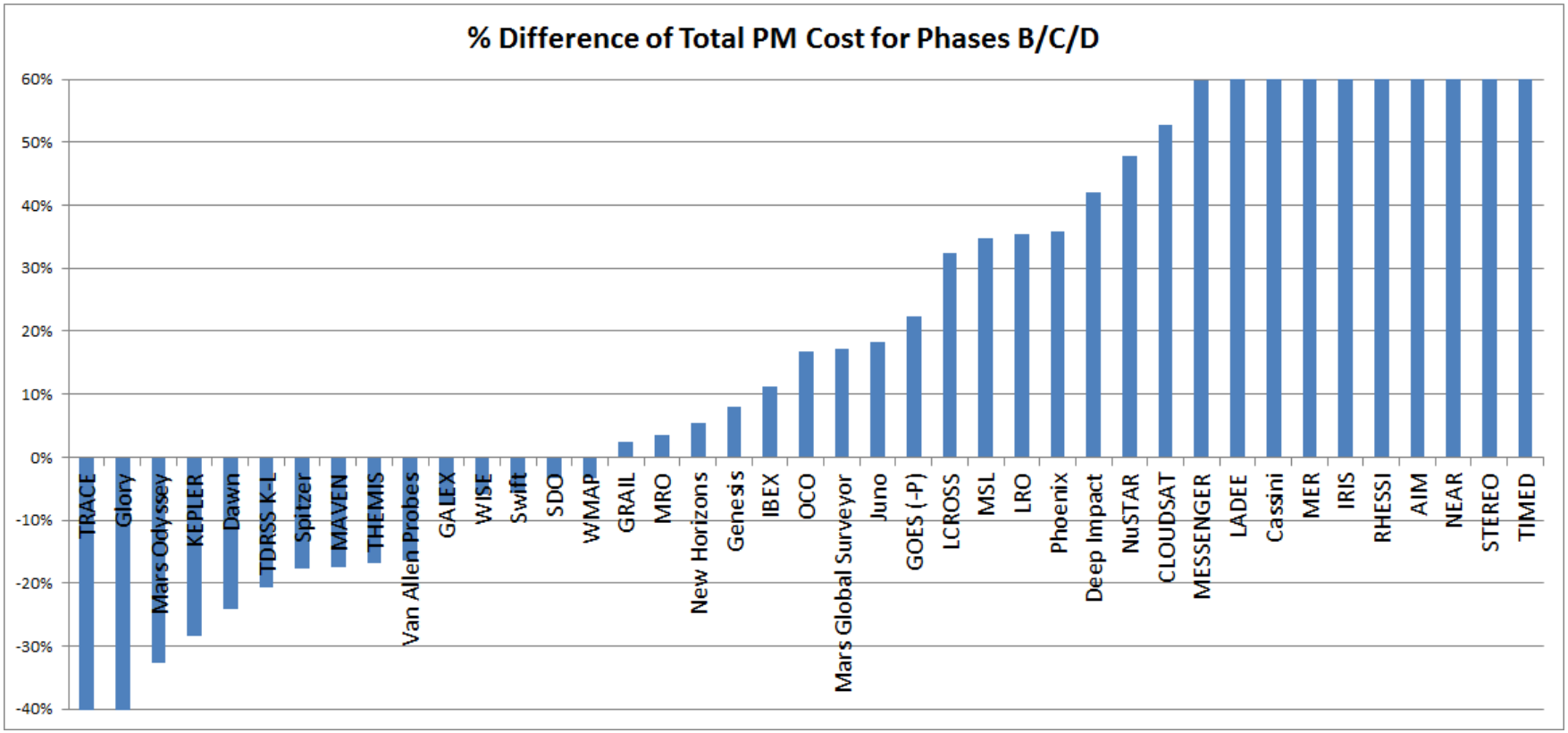
BACKUP

CONSTRUCTIVE APPROACH DETAILS

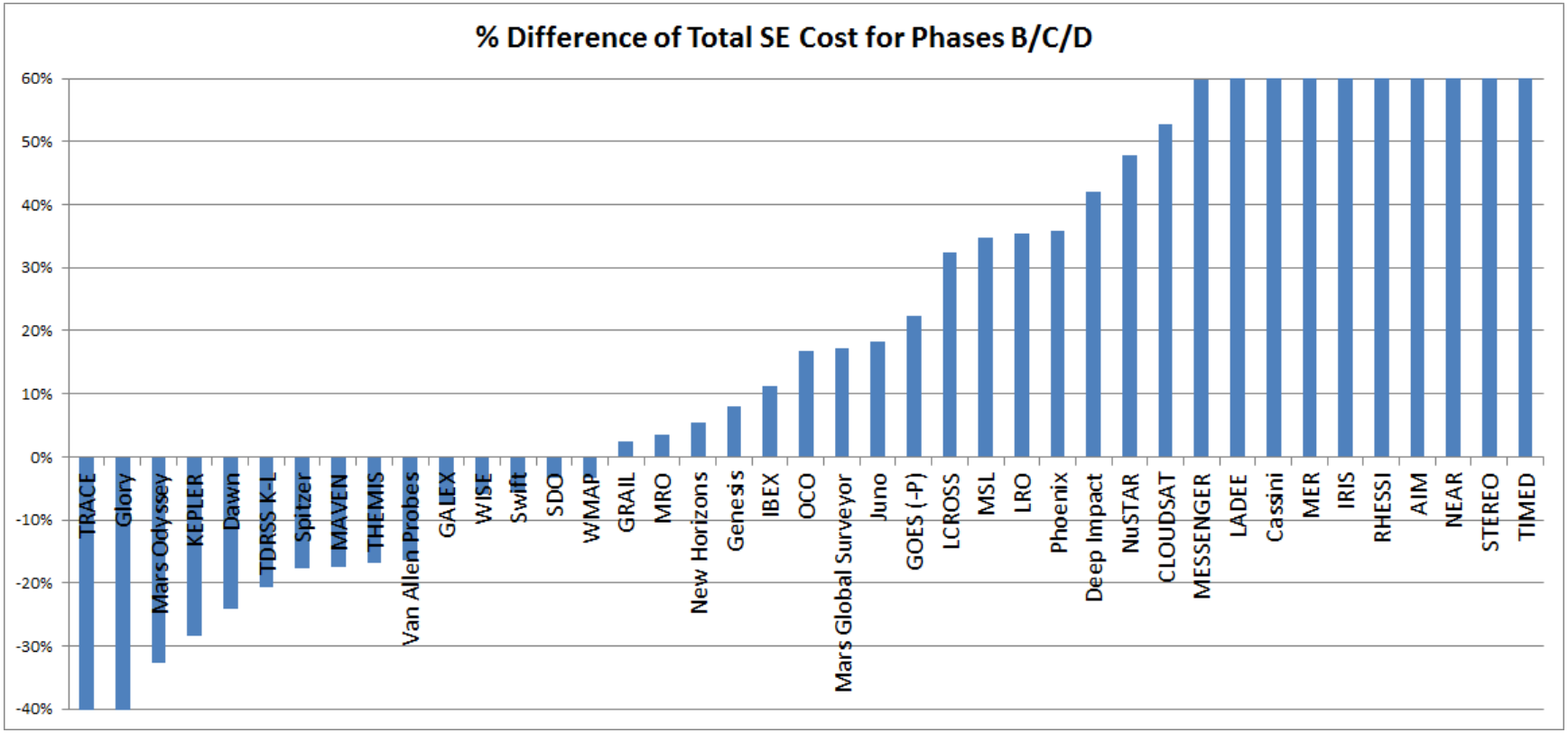
Constructive Approach Results
Total PM/SE/MA/I&T



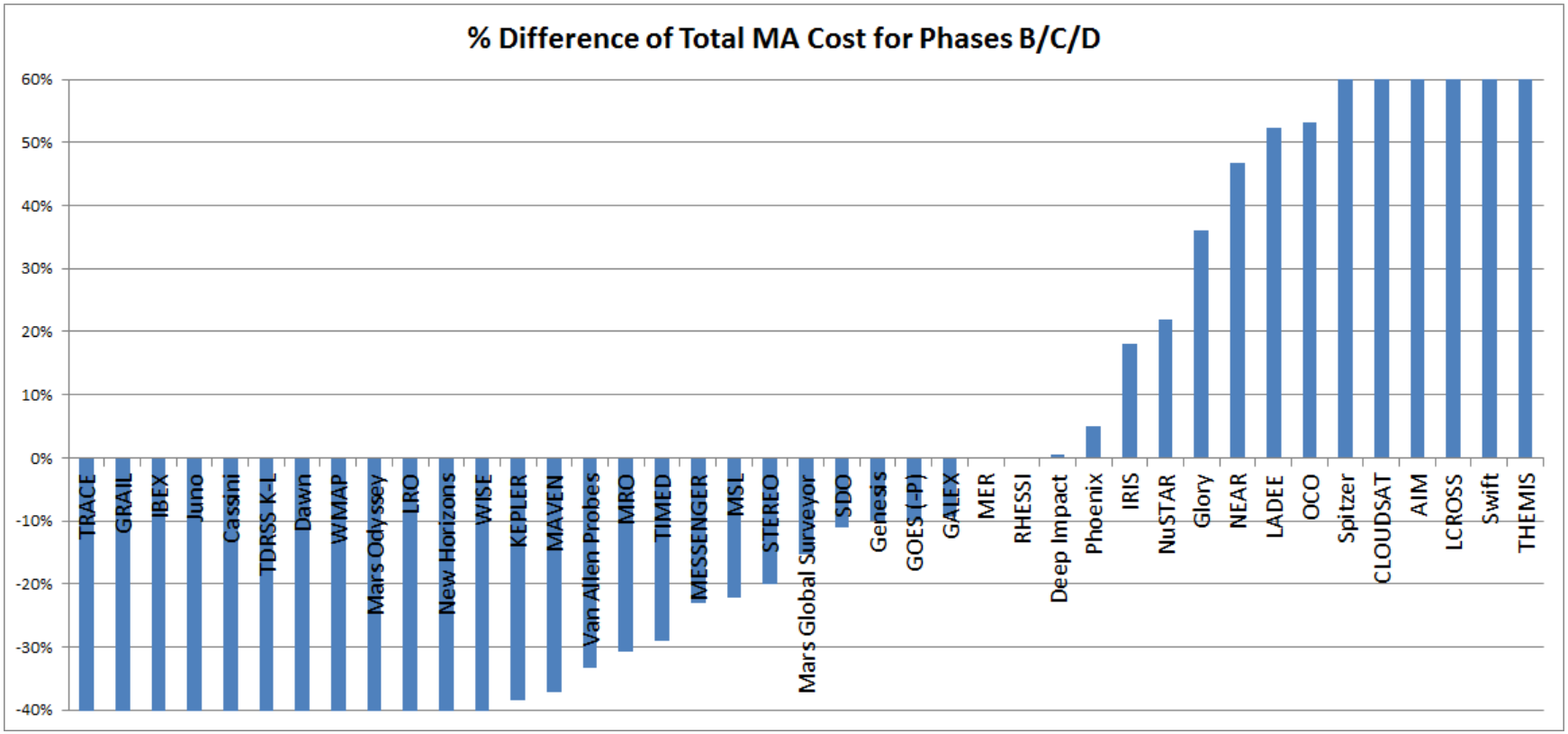
Constructive Approach Results
Total PM



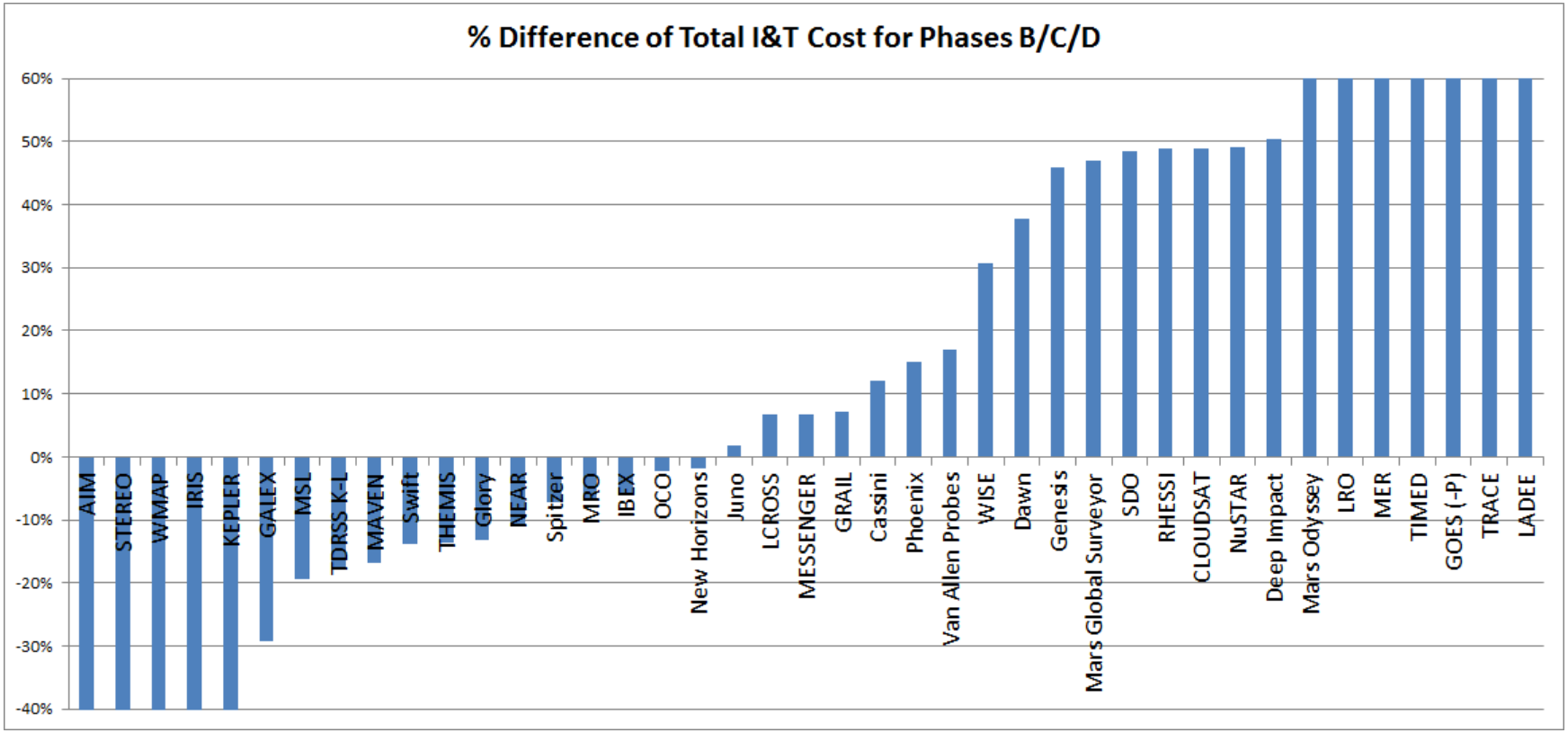
Constructive Approach Results
Total SE



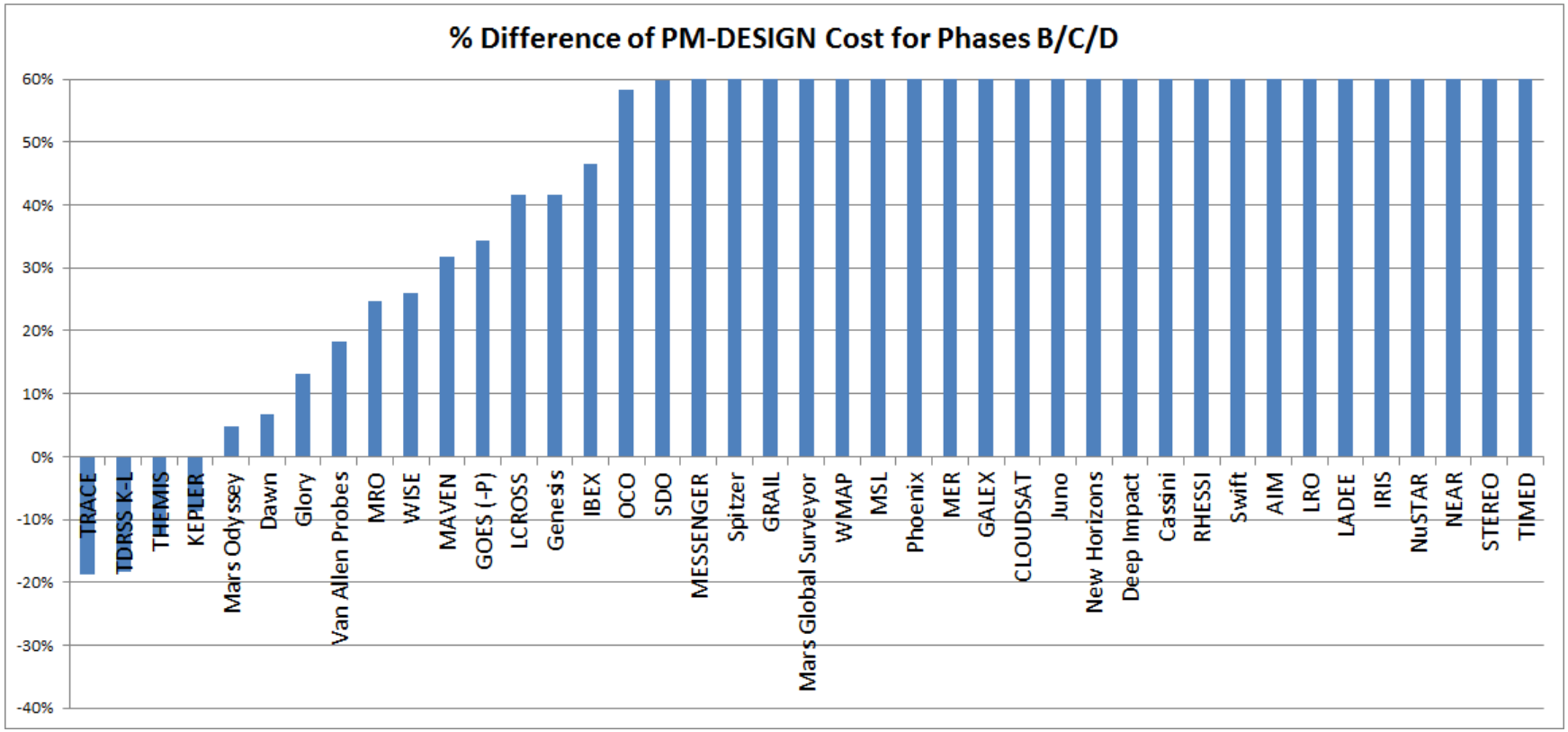
Constructive Approach Results
Total MA



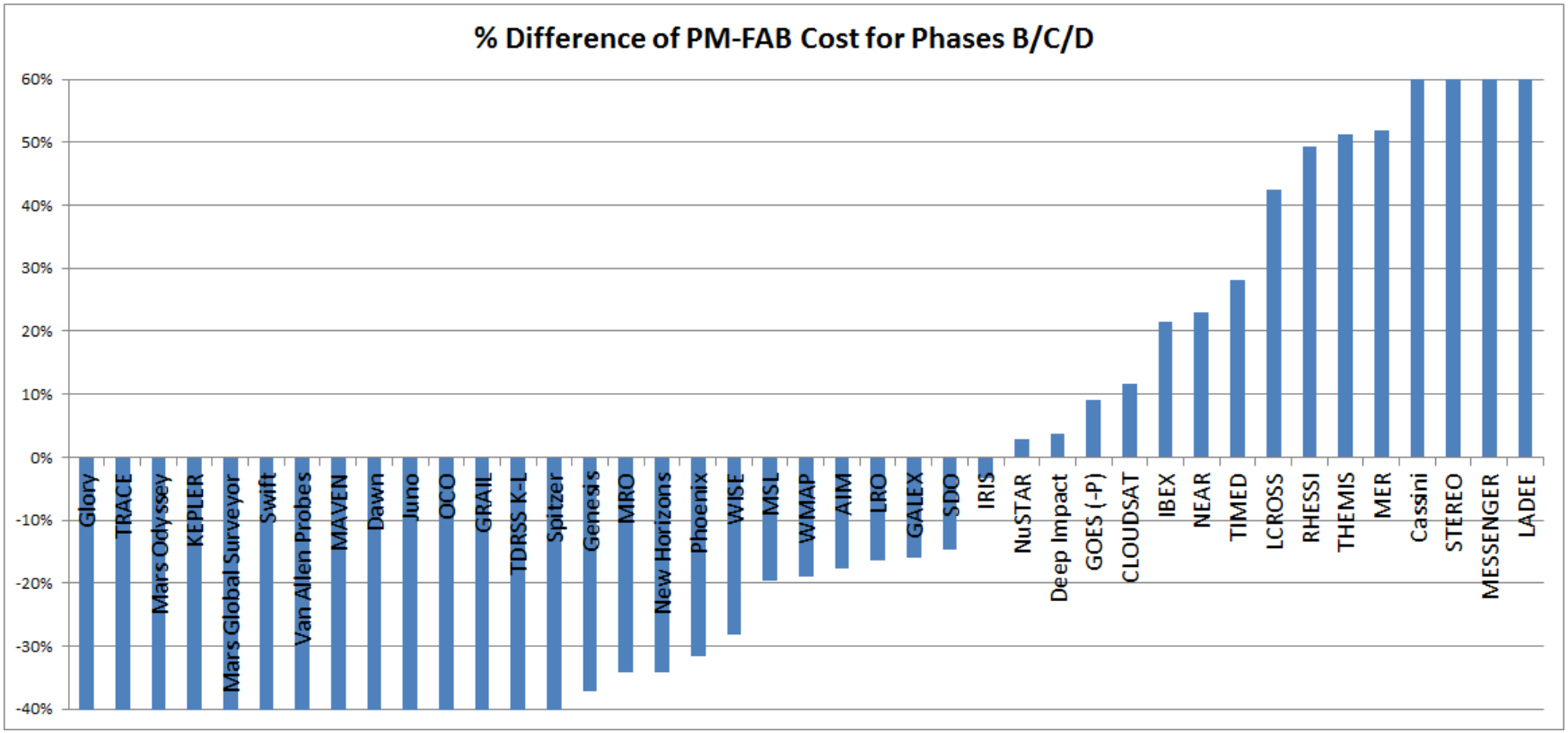
Constructive Approach Results
Total I&T



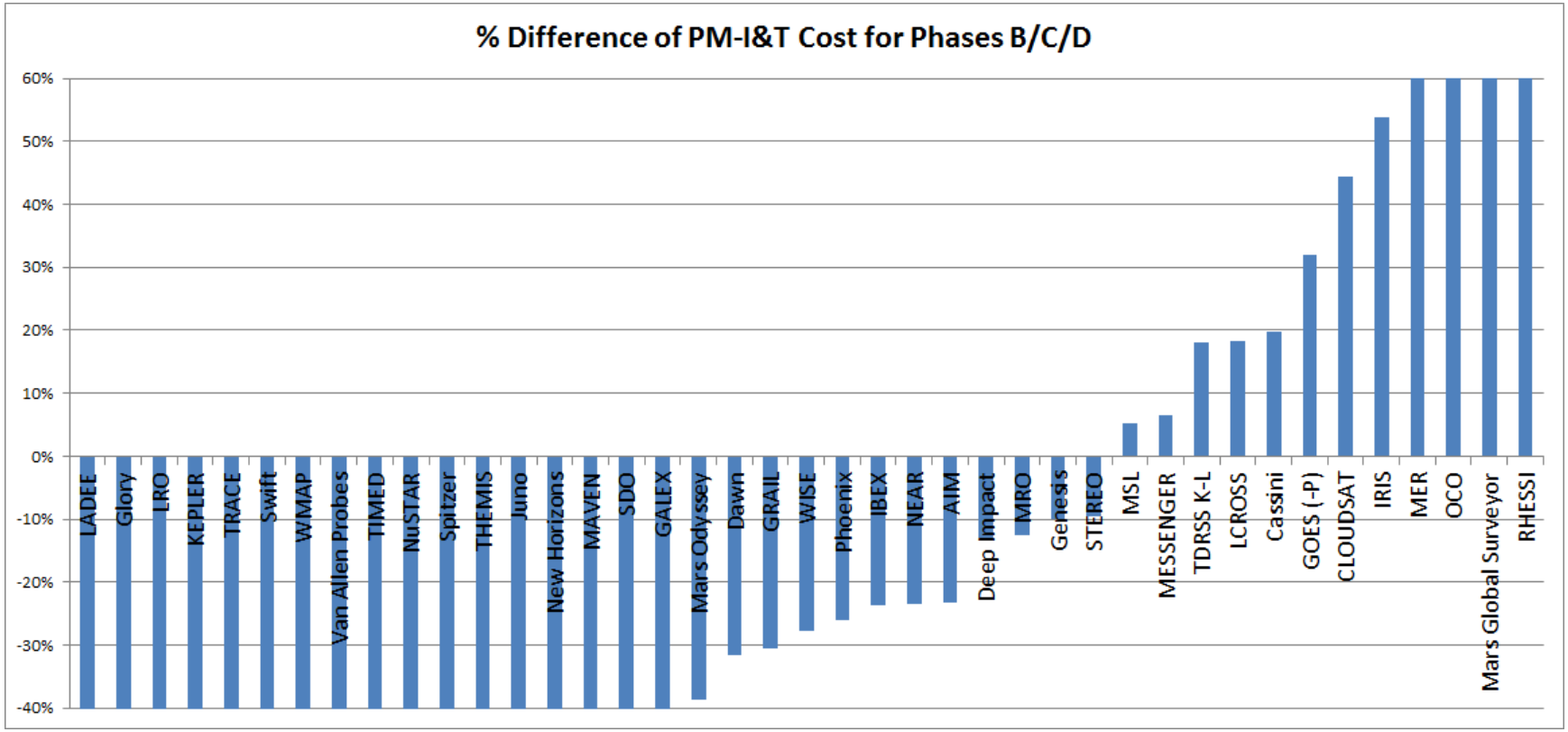
Constructive Approach Results
PM - DESIGN



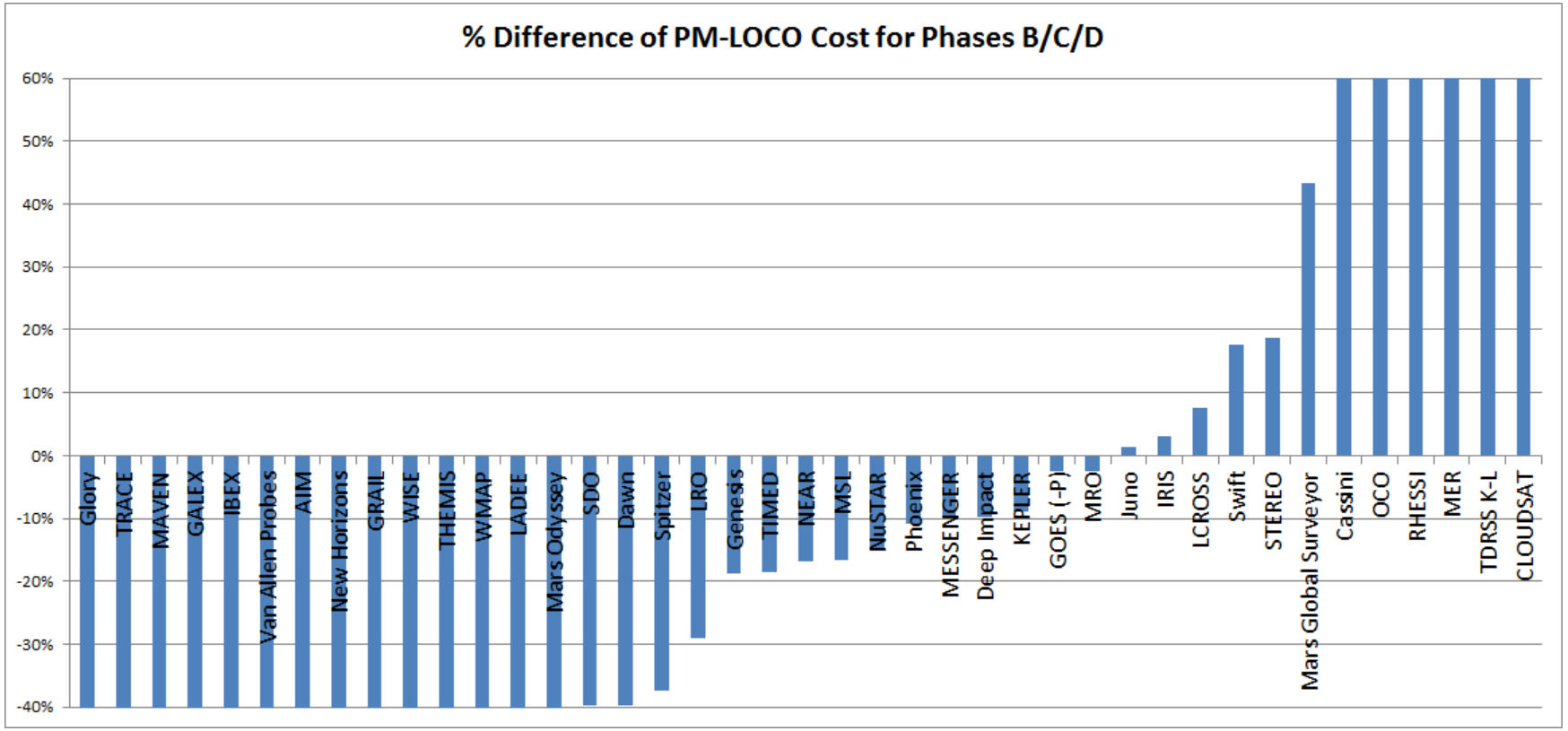
Constructive Approach Results
PM - FAB



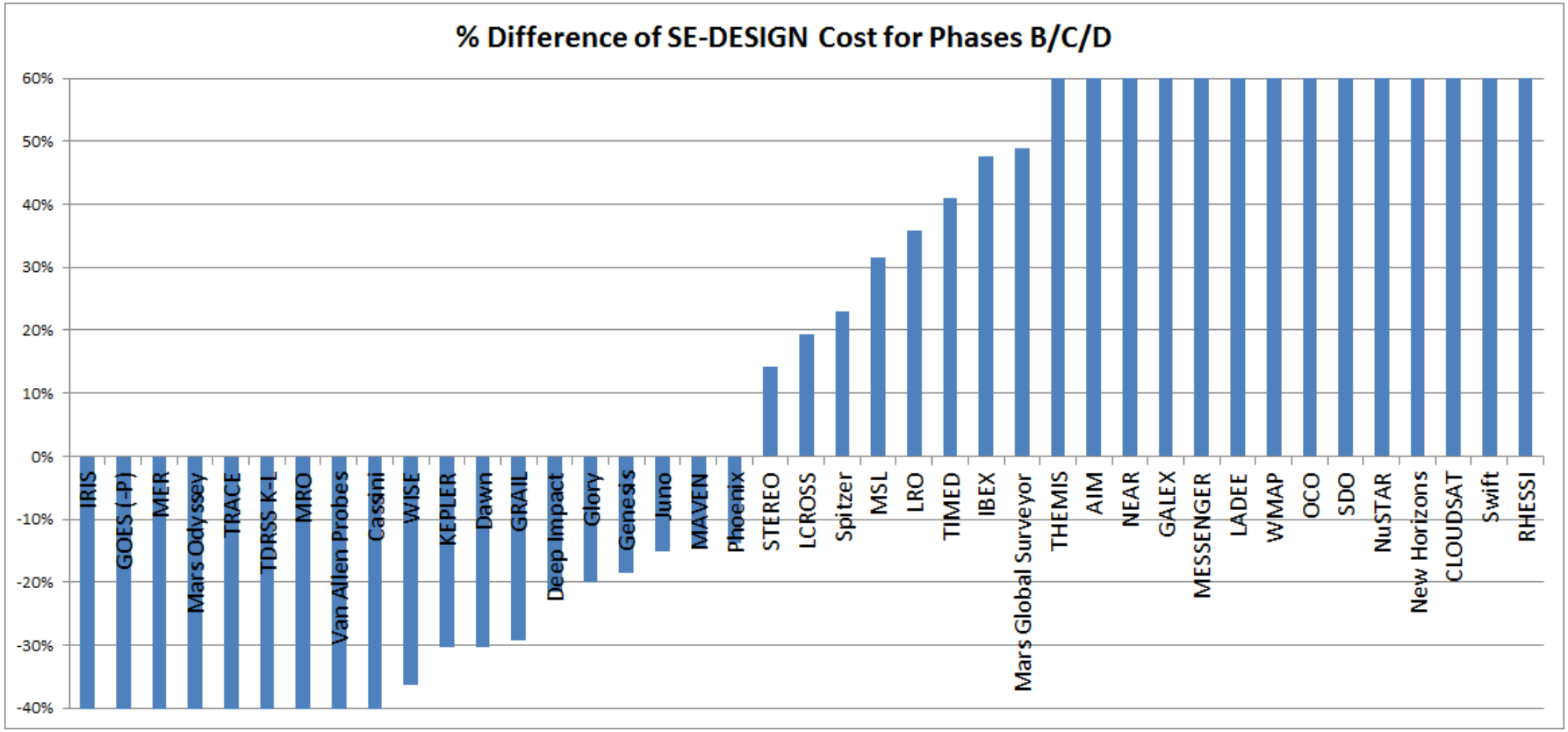
Constructive Approach Results
PM – I&T



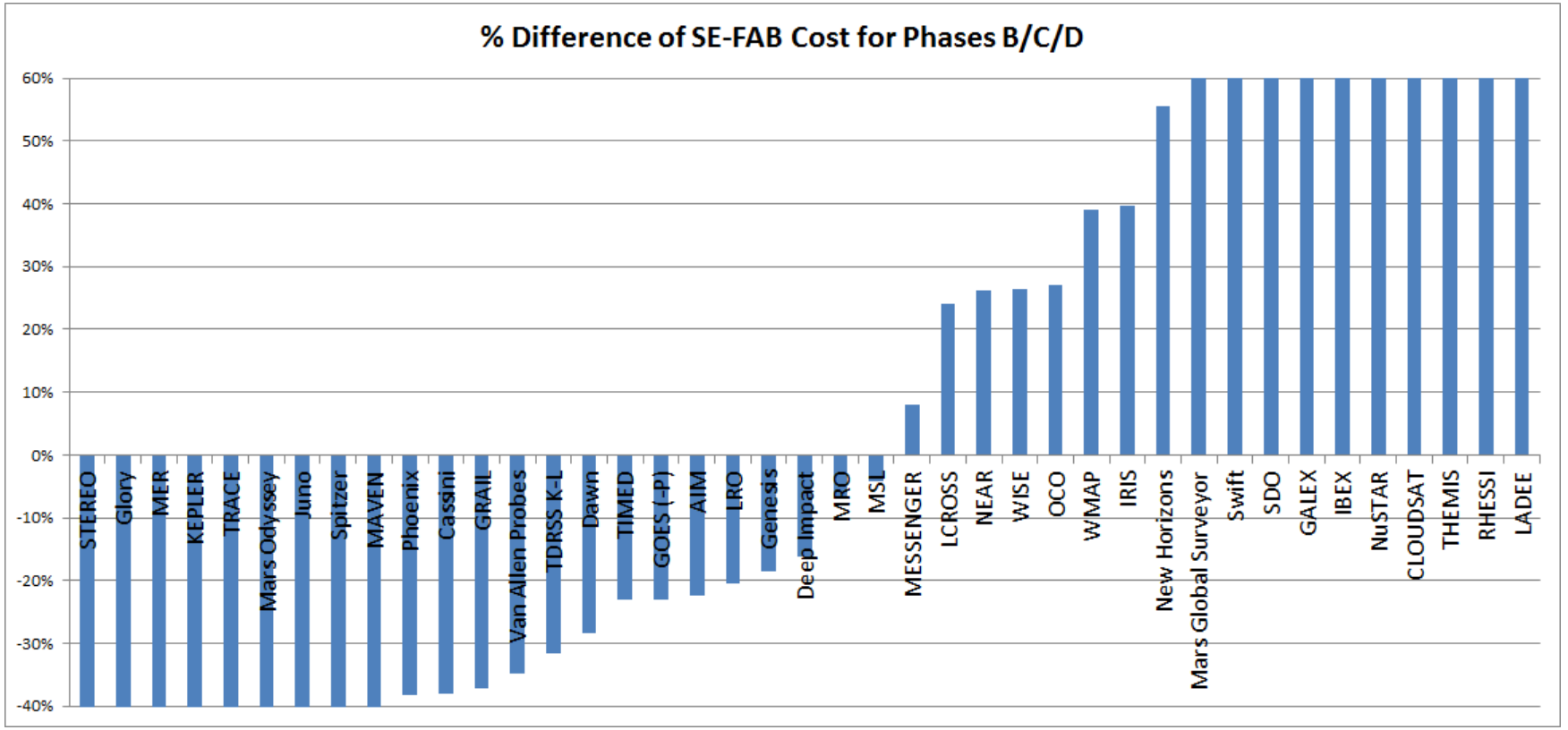
Constructive Approach Results
PM - LOCO



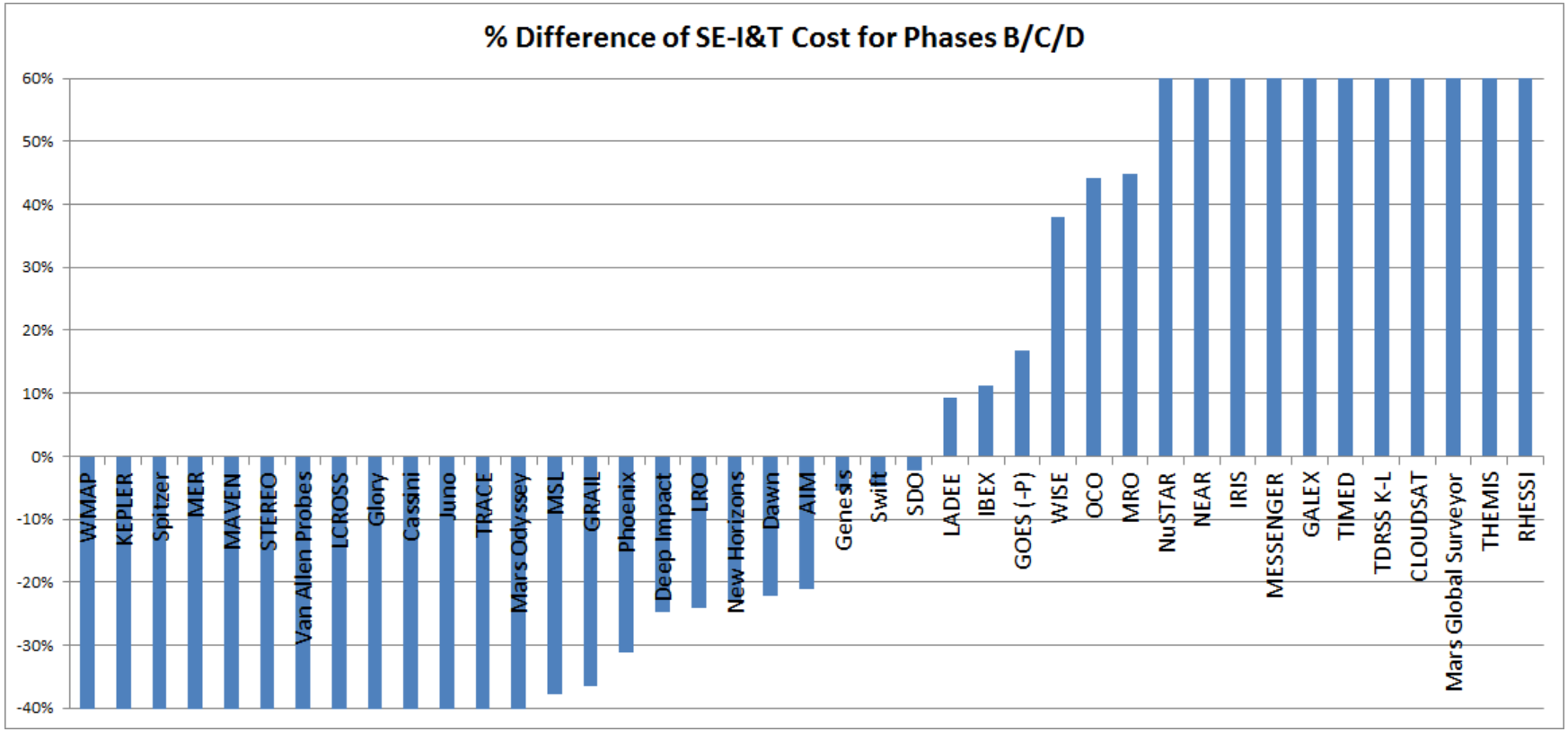
Constructive Approach Results
SE - DESIGN



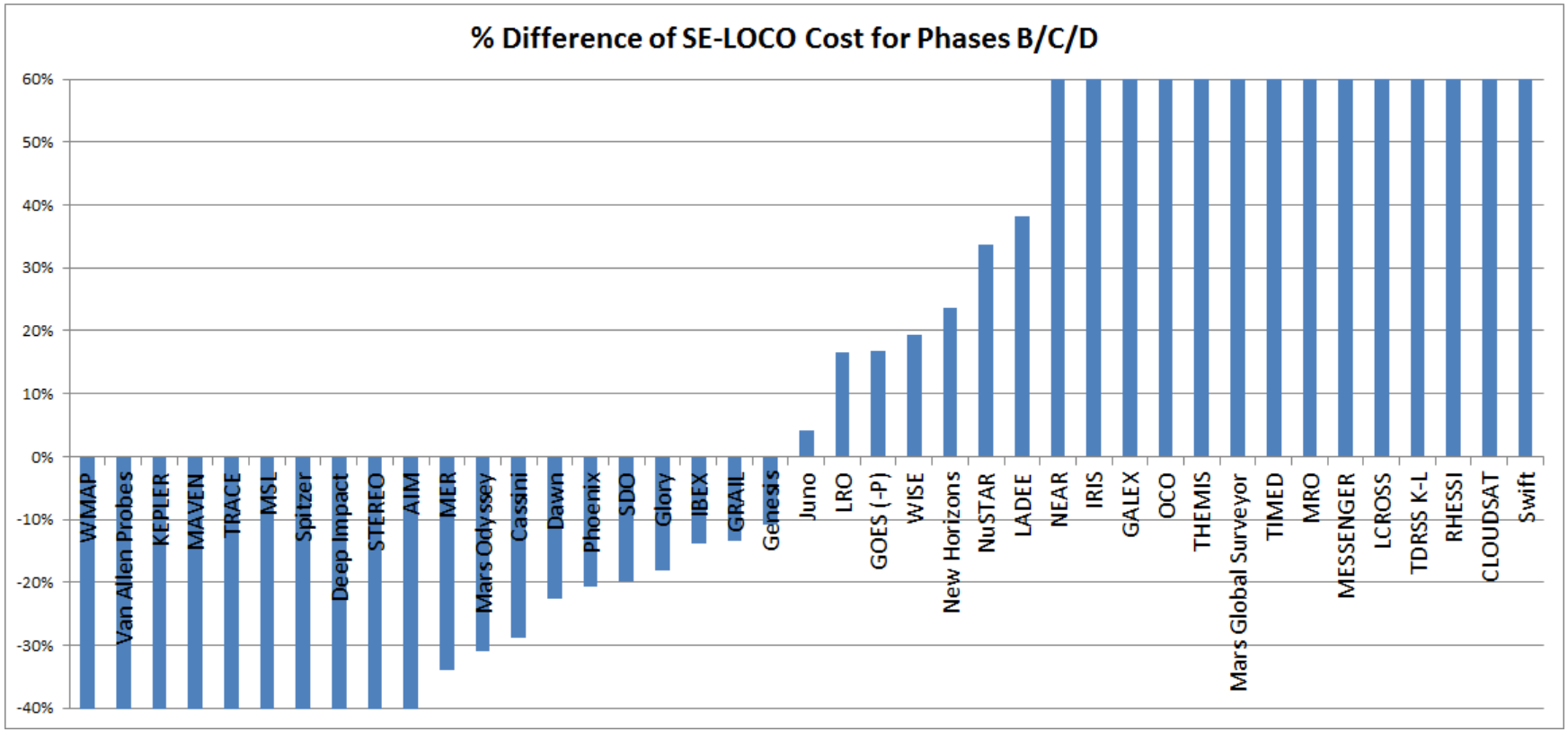
Constructive Approach Results
SE - FAB



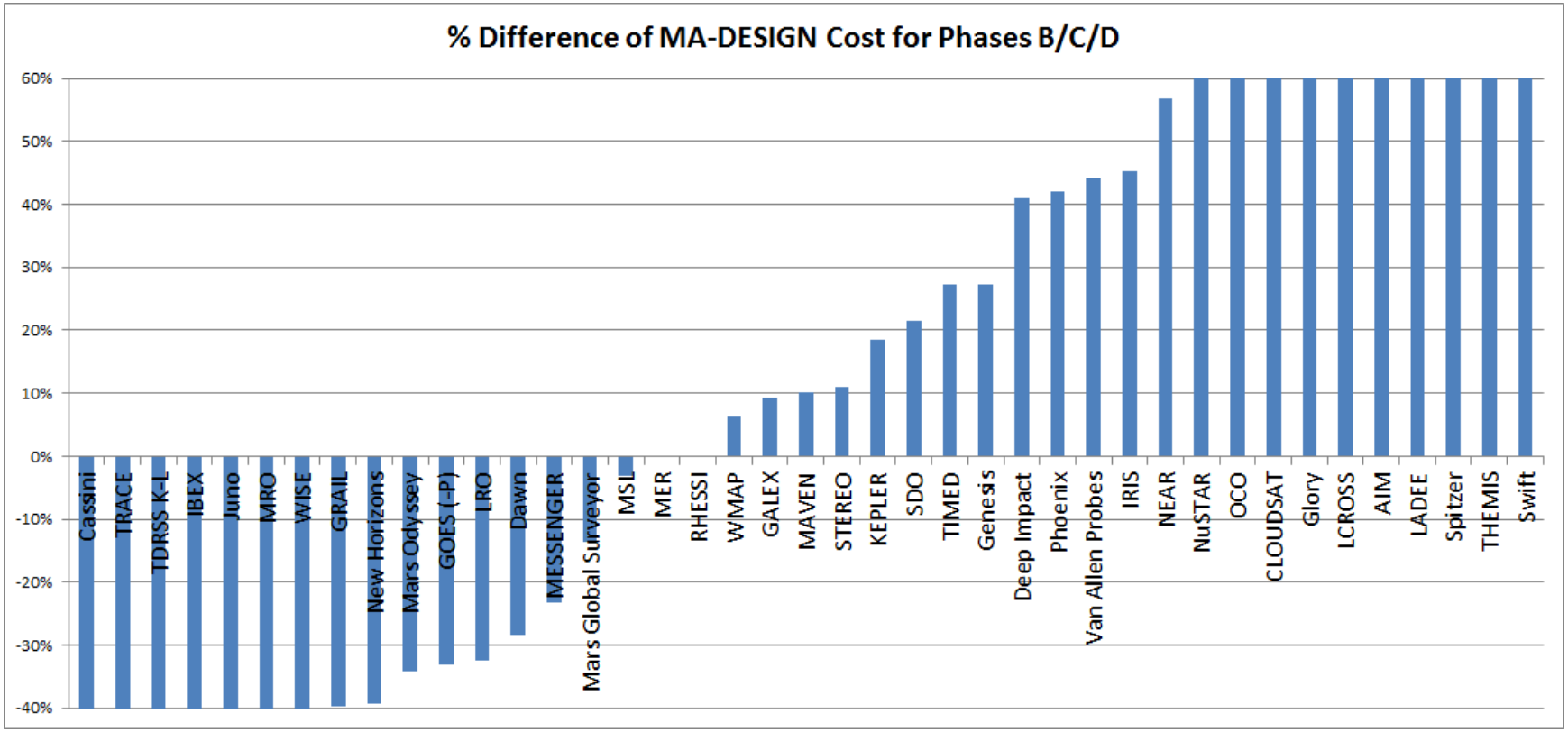
Constructive Approach Results
SE – I&T



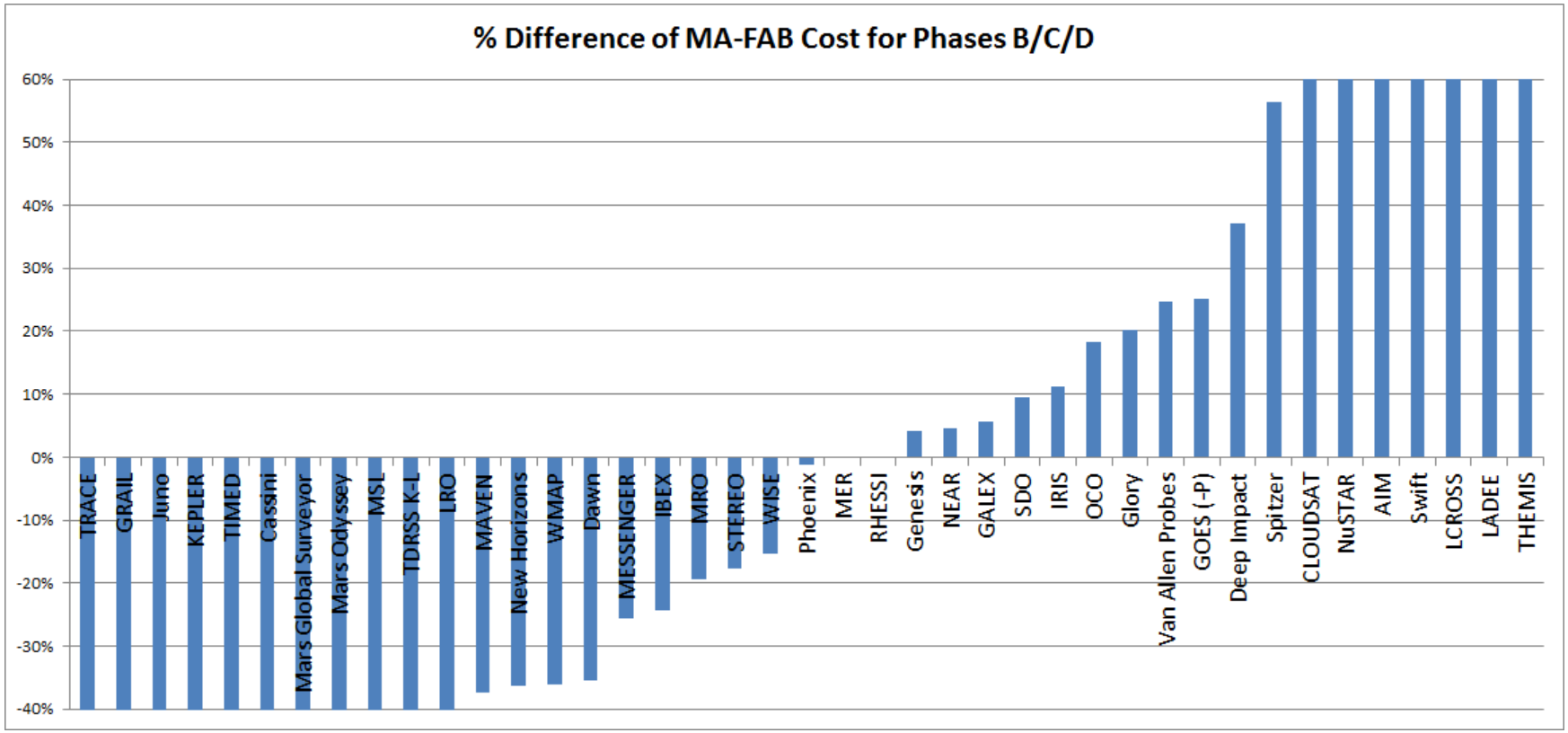
Constructive Approach Results
SE - LOCO



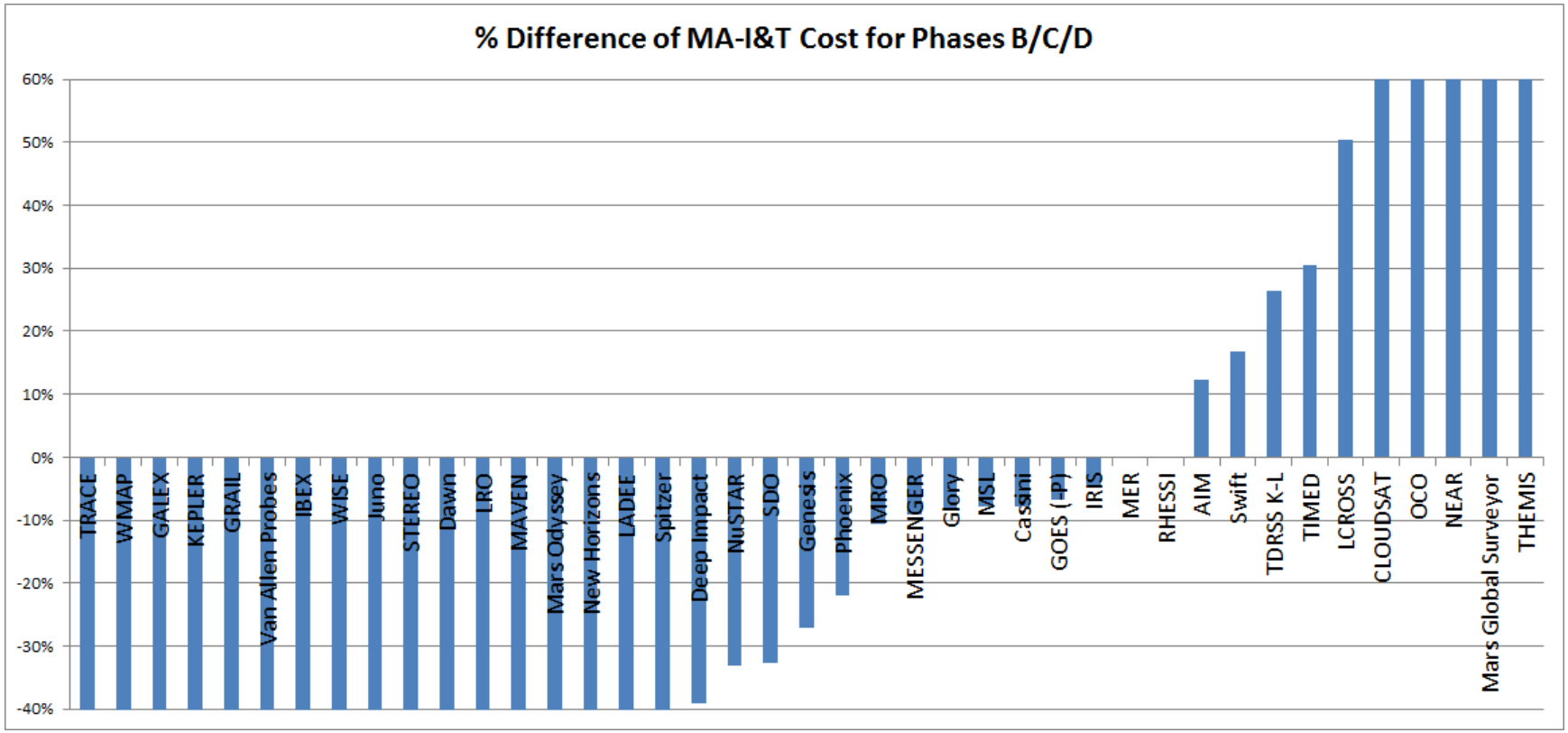
Constructive Approach Results
MA - DESIGN



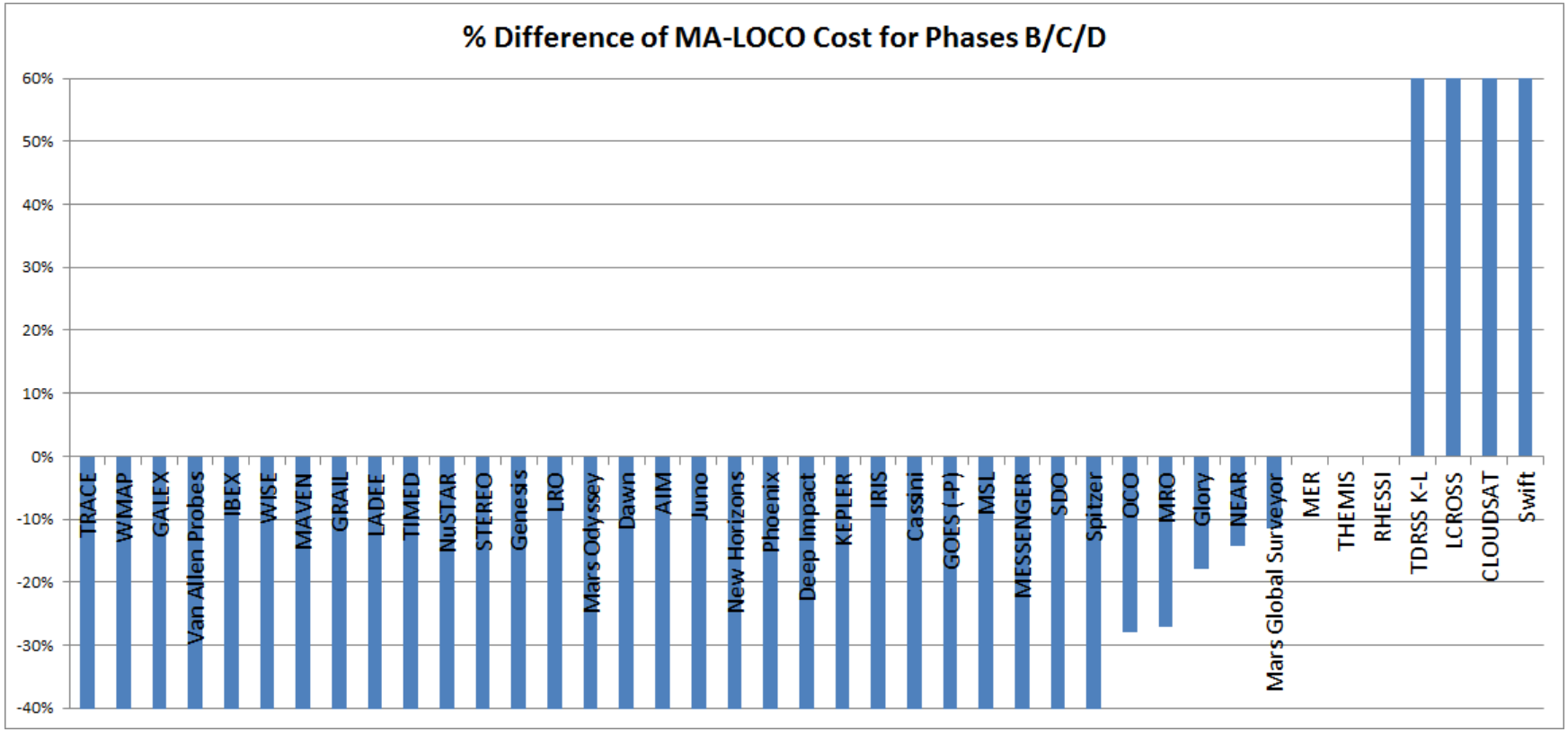
Constructive Approach Results
MA - FAB



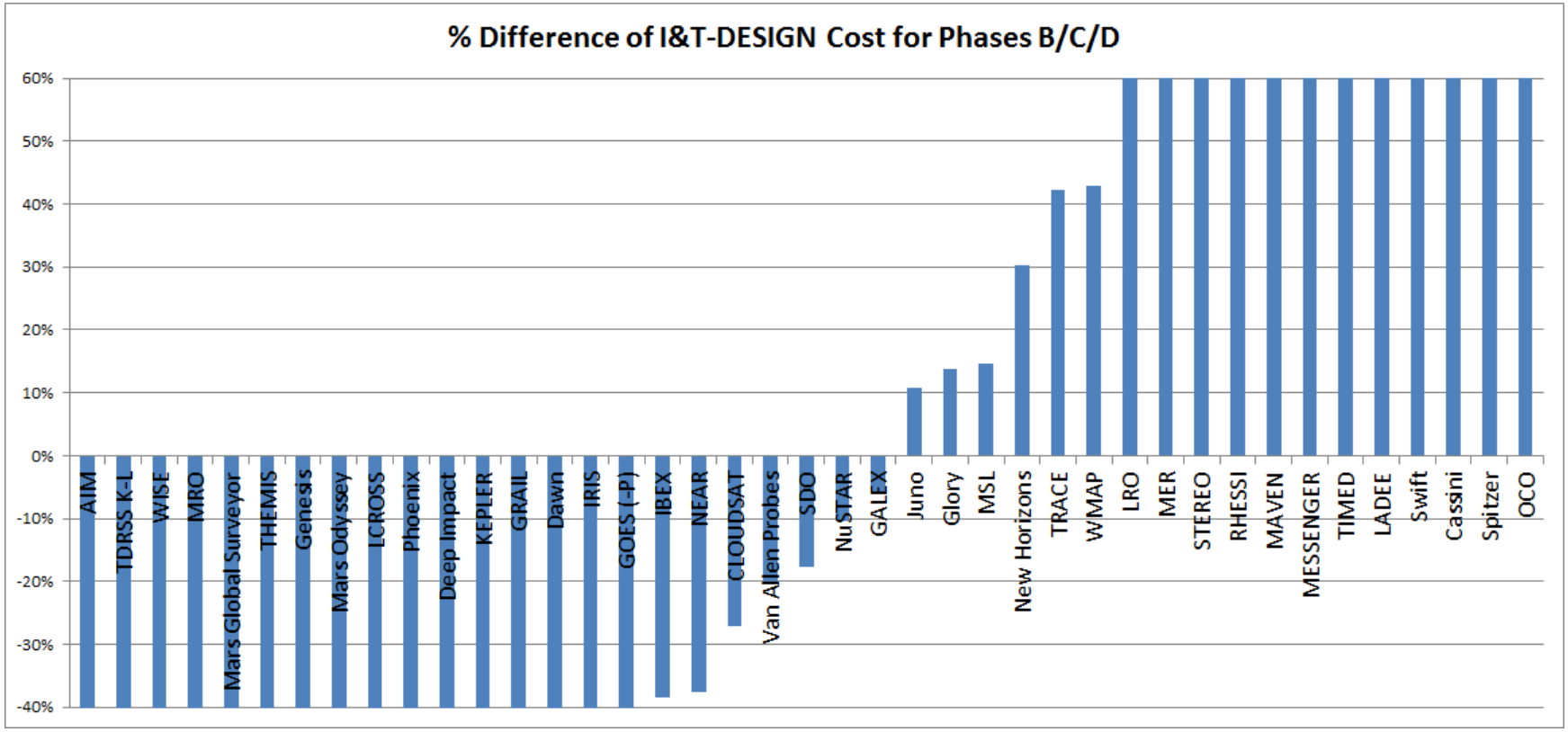
Constructive Approach Results
MA – I&T



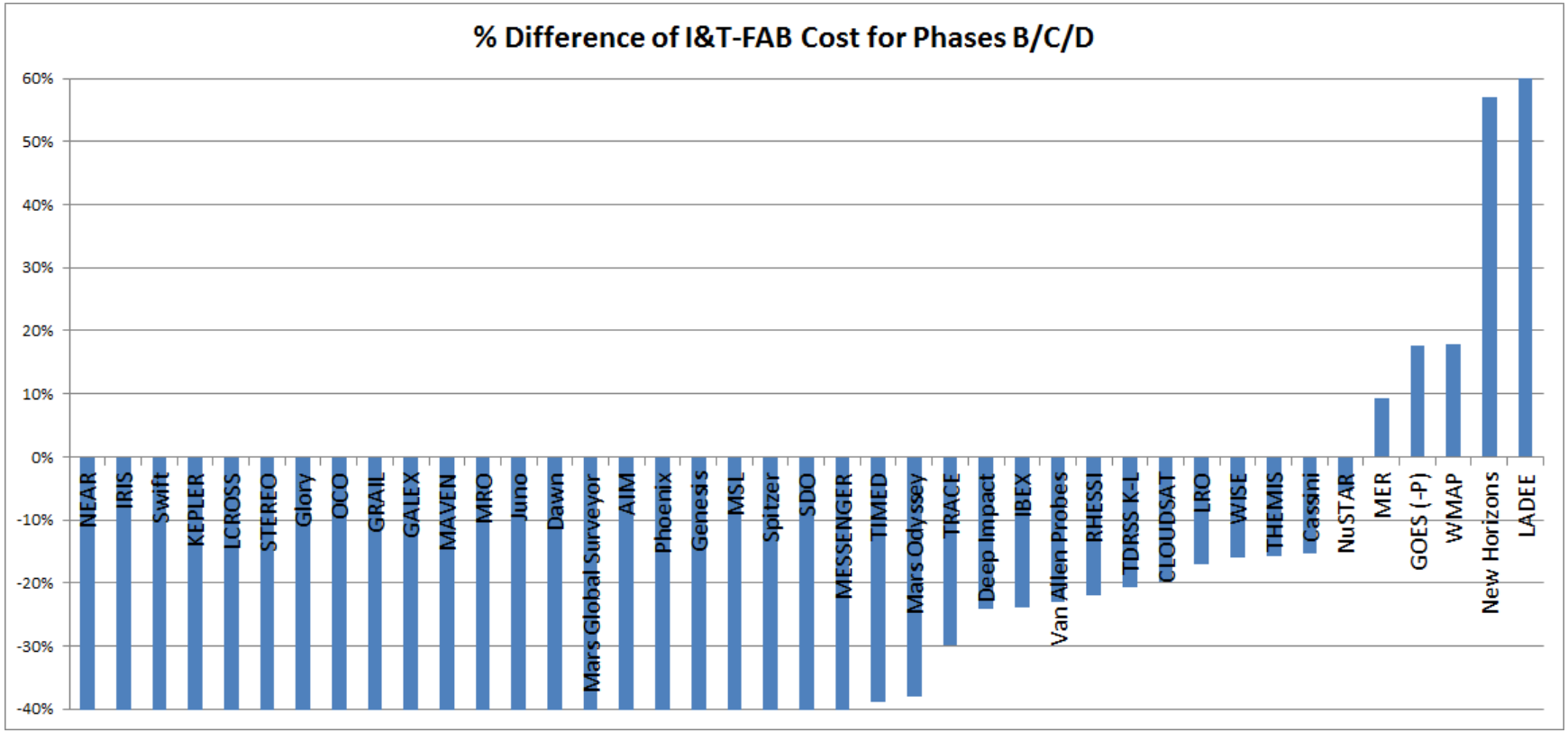
Constructive Approach Results
MA - LOCO



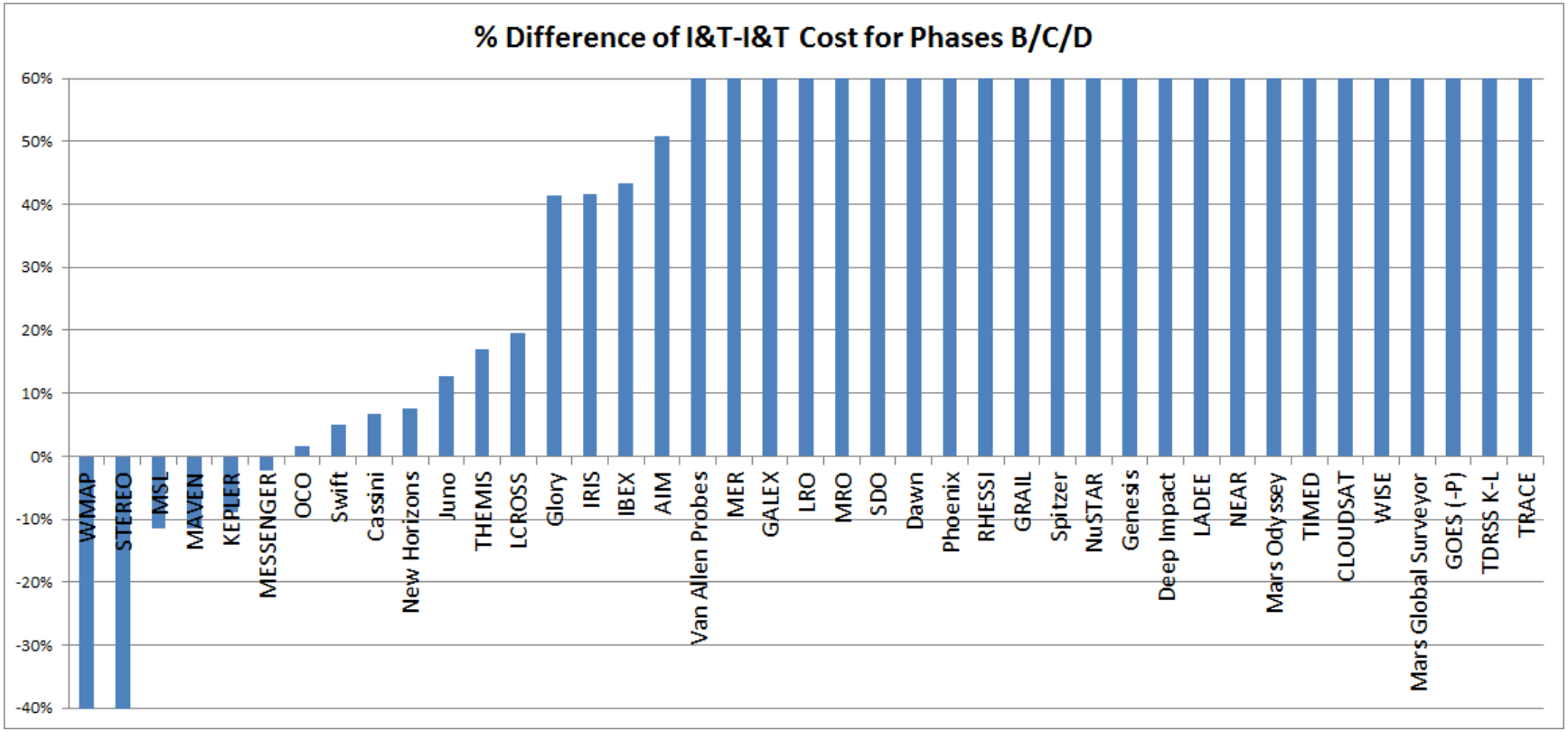
Constructive Approach Results
I&T - DESIGN



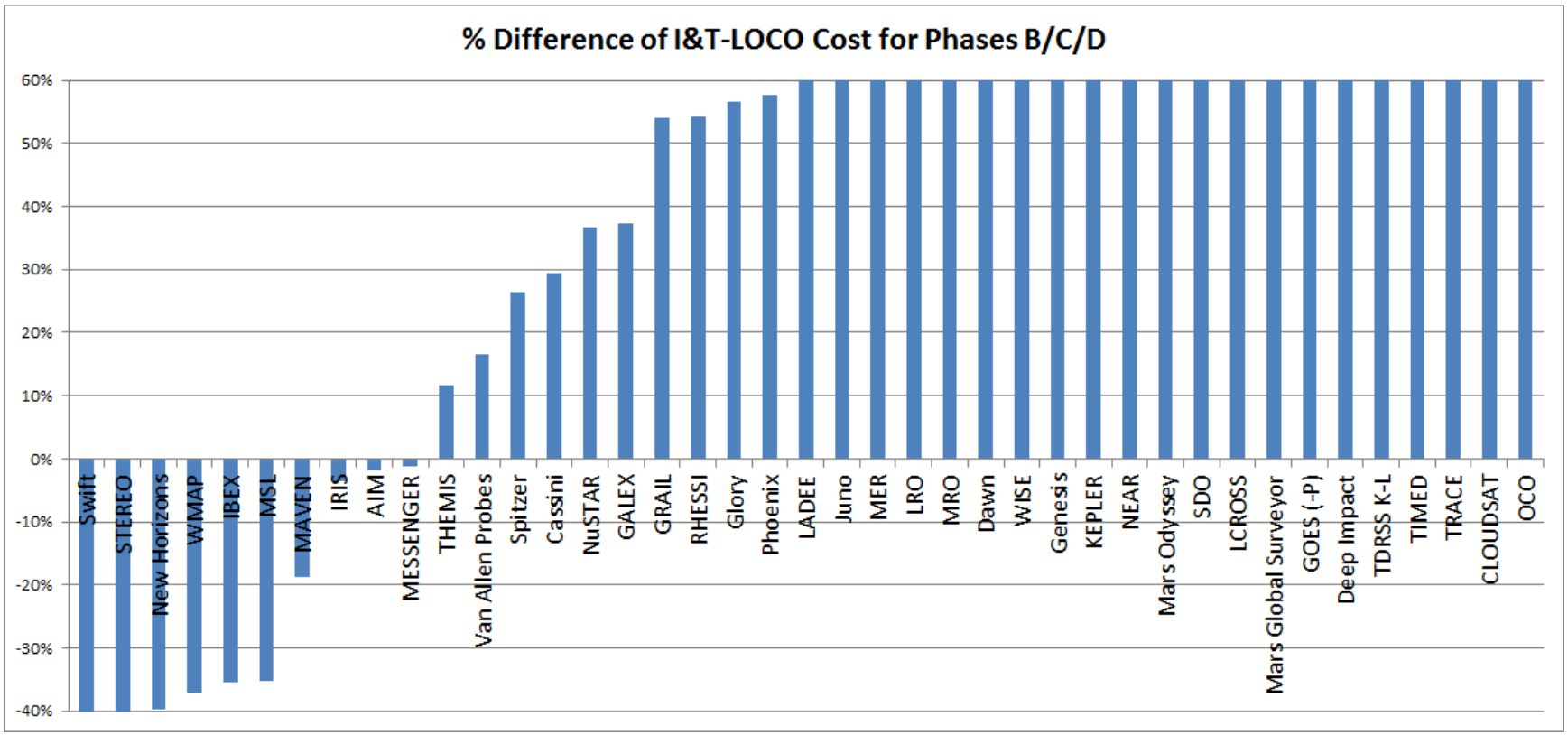
Constructive Approach Results
I&T - FAB



Constructive Approach Results
I&T – I&T



Constructive Approach Results
I&T - LOCO



Constructive Approach Results
Data Ranges and Input Weightings

Engineering Cost Office

	DB LOW $K/mo DES	DB LOW $K/mo FAB	DB LOW $K/mo I&T	DB LOW $K/mo LOCO	DB HIGH $K/mo DES	DB HIGH $K/mo FAB	DB HIGH $K/mo I&T	DB HIGH $K/mo LOCO
PM	59.1	36.7	65.4	3.3	2,005	1,650	1,150	1,122
SE	25.0	13.3	13.2	0.2	3,358	2,525	2,248	2,768
MA	25.3	6.4	2.1	0.2	1,573	1,765	1,163	731
I&T	0.3	2.9	10.7	0.1	1,857	1,763	3,762	6,170

Weightings

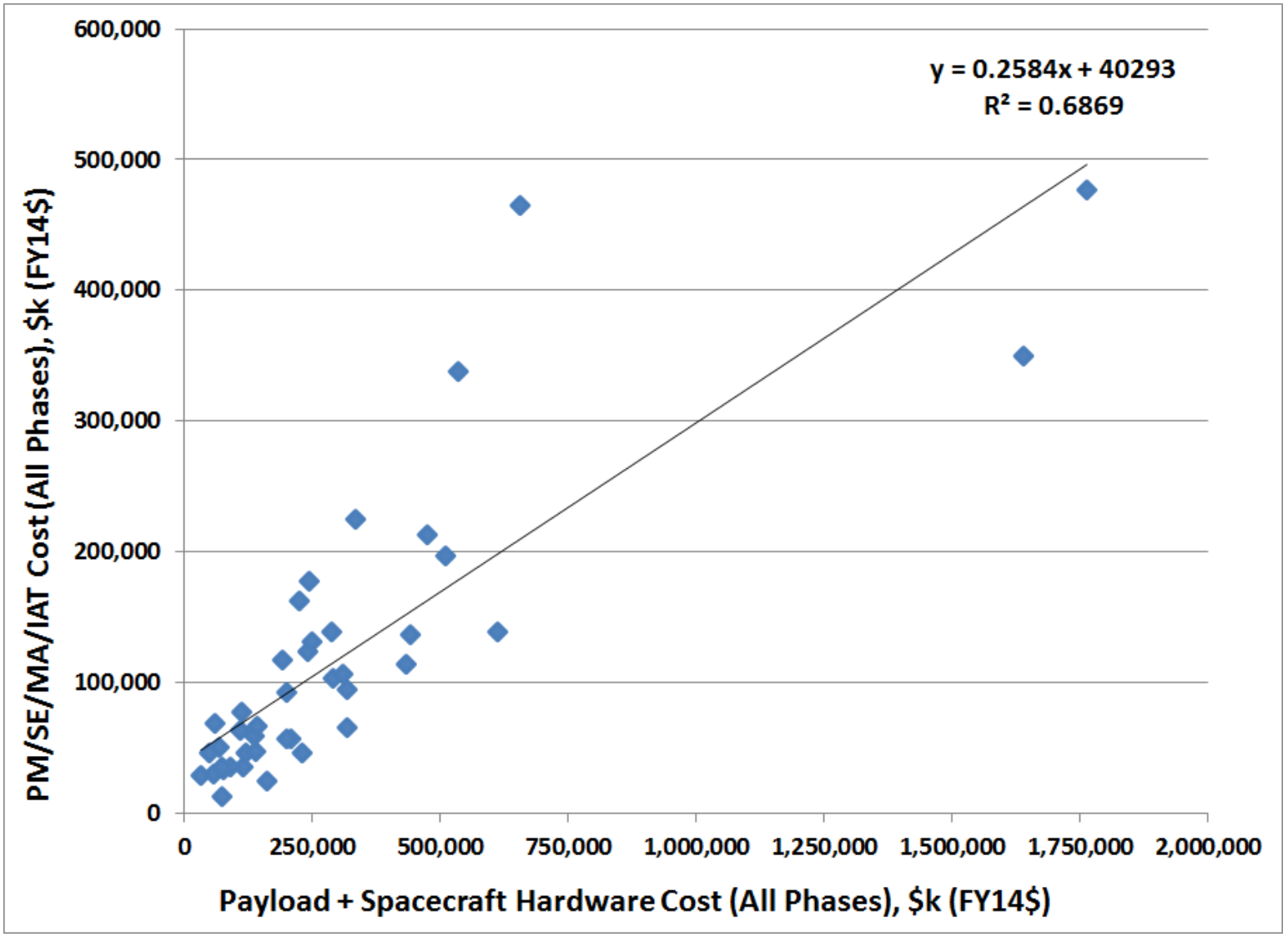
Input #	DIRECTED or AO	MISSION RISK CLASS	MISSION DESTINATION	FLIGHT SYSTEM TYPE	MULTIPLE FLIGHT SYSTEMS ?	LEAD ORGANIZATION	FLIGHT SYSTEM ORGANIZATION	PAYLOAD ORG.	LEAD ORGANIZATION EXPERIENCE	FLIGHT SYSTEM LEAD ORG. EXPERIENCE	PAYLOAD LEAD ORG. EXPERIENCE	FLIGHT SYSTEM MASS (kg)	FLIGHT SYSTEM POWER (W)	FLIGHT SYSTEM POWER/MASS RATIO (W/kg)	NUMBER OF SPACECRAFT	FLIGHT SYSTEM HERITAGE & TRL	PARTS RATING	# OF KEY SPACECRAFT CONTRACTORS	PAYLOAD MASS (kg)	PAYLOAD POWER (W)	PAYLOAD POWER/MASS RATIO (W/kg)	# OF PAYLOAD ELEMENTS	# OF KEY PAYLOAD CONTRACTORS	IN-HOUSE SCOPE	INTERNATIONAL PARTICIPATION (HW)
1	0.5	0.35	0.3	0.1	0	0.05	0.05		0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
2	1.2	0.5	0.6	0.3	1	0.1	0.1		0.4	0.4	0.4	1	1	1	1	1	1	1	1	1	1	1	1	0.4	1
3		0.75	0.6	0.4		0.6	0.6		0.6	0.6	0.6													0.6	
4		1.8	0.7	0.6		1.2	1.3		0.8	0.8	0.8													0.8	
5			0.9	0.8		1.8	1.2		1	1	1													1	
6			1.747	1.5																					
7			2																						

Correlations

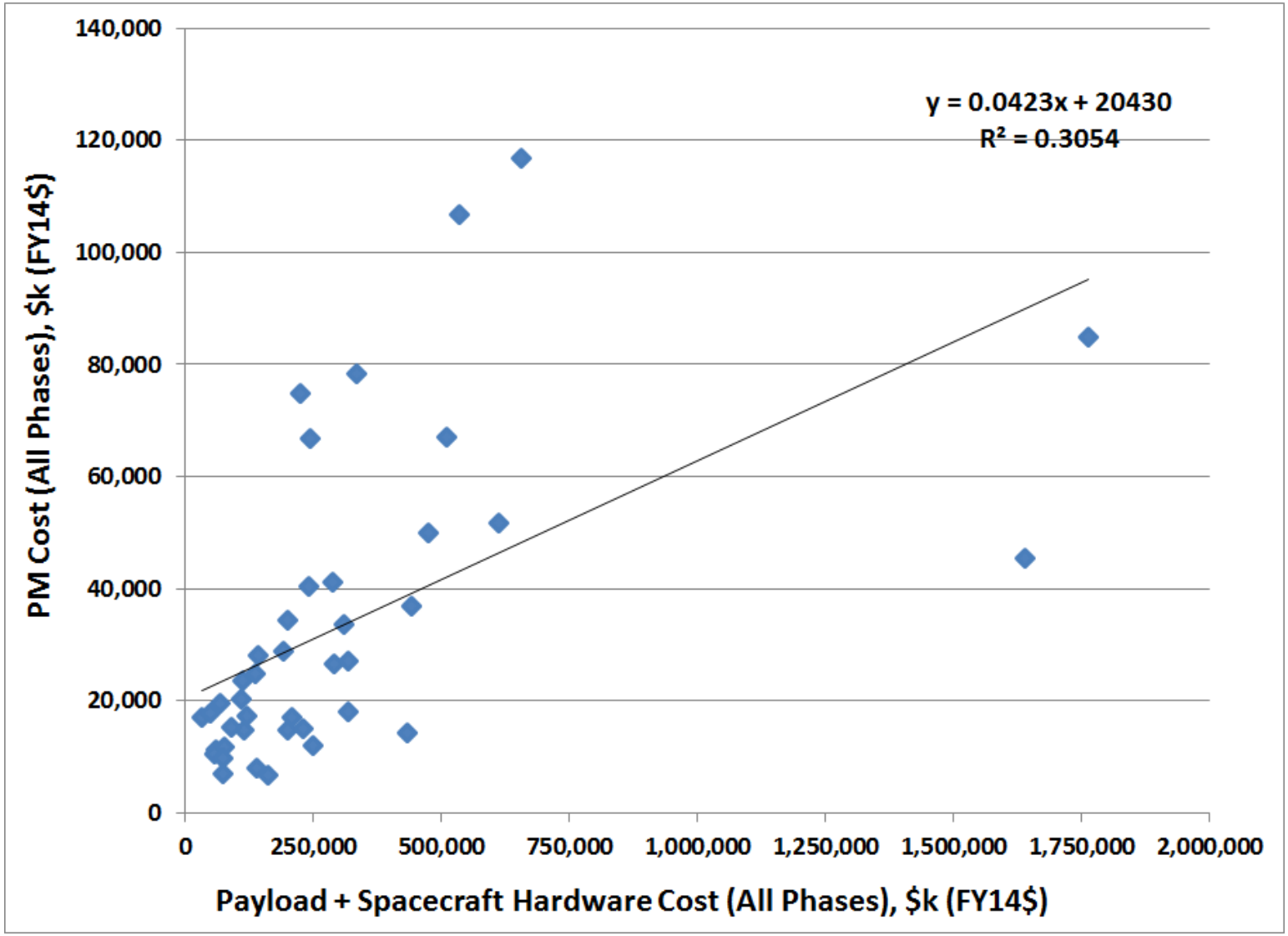
		DIRECTED or AO	MISSION RISK CLASS	MISSION DESTINATION	FLIGHT SYSTEM TYPE	MULTIPLE FLIGHT SYSTEMS ?	LEAD ORGANIZATION	FLIGHT SYSTEM ORGANIZATION	PAYLOAD ORG.	LEAD ORGANIZATION EXPERIENCE	FLIGHT SYSTEM LEAD ORG. EXPERIENCE	PAYLOAD LEAD ORG. EXPERIENCE	FLIGHT SYSTEM MASS	FLIGHT SYSTEM POWER	FLIGHT SYSTEM POWER/MASS RATIO	NUMBER OF SPACECRAFT	FLIGHT SYSTEM HERITAGE & TRL	PARTS RATING	# OF KEY SPACECRAFT CONTRACTORS	PAYLOAD MASS	PAYLOAD POWER	PAYLOAD POWER/MASS RATIO	# OF PAYLOAD ELEMENTS	# OF KEY PAYLOAD CONTRACTORS	IN-HOUSE SCOPE	INTERNATIONAL PARTICIPATION (HW)
PM	DES	0	1.05	0.2625	0	0.525	0	0.525	0.7875	0.7875	0.525	1.3125	0.7875	1.3125	0	0	0	1.05	1.05	1.3125	0	0	0	0	0
	FAB	0	0.525	0.2625	0	0.525	0	0.7875	0.525	0.7875	0.525	0.7875	0.7875	1.05	0.525	0	0	1.05	0.525	0.525	0.525	0	0	0	0
	I&T	0	0	0.2625	0	0.525	0	0.7875	0	0	0	0	0	0.7875	0.525	0	0	0.7875	0.525	0	0	0	0	0	0	0
	LOCO	0	0	0.525	0.525	0.525	0.525	0.525	0	0	0	0.525	1.05	0.525	0	0	0	0.525	1.05	0	0	0.525	0	0	0	0
SE	DES	0.4	0.8	0.2	0	0.4	0	0.6	0.6	0.6	0.4	1	0.4	0.6	0	0	0	0.6	0	0	0.6	0.4	0	0	0	0
	FAB	0.4	0.6	0.6	0.8	0.4	0.64	0.8	0.4	0.4	0	0.4	0.8	0.4	0	0	0	0.8	0.6	0	0	0.4	0	0	0	0
	I&T	0	0.4	0.4	0.8	0.4	0.64	0.6	0	0.4	0	0	0.8	0	0	0	0	0.8	0.6	0	0	0	0	0	0	0
	LOCO	0	0.4	0.4	1	0.4	0.8	0.6	0	0.4	0	0	1.2	0.4	0	0	0	0.8	0.6	0	0.4	0.8	0	0	0	0
MA	DES	0	1.25	0.5	0	0.5	0	0.5	0.5	0	0	1	1	0.75	0	0	0	1.25	0	0.5	0.75	0	0	0	0.5	0
	FAB	0	0.75	1	0	0.5	0	0.5	0	0	0	0.75	1.5	0.5	0	0	0.5	1.5	0.5	0	0.5	0	0.75	0.5	0.5	0
	I&T	0	0	0.75	0	0.5	0	0.5	0	0	0	0	0.5	0.5	0	0	0.5	1	0	0	0	0	0	0.5	0	0
	LOCO	0	0.5	0.5	0	0.5	0	0.5	0	0	0	0	0.5	0.75	0.5	0	0.5	0.75	0.5	0	0	0	0	0	0	0
I&T	DES	0	0.75	0.25	0	0.5	0	0	0.5	0.5	0.5	1.25	0.5	0.75	0	0	0	0.75	0	0.75	1.25	0	0	0	0	0
	FAB	0	0	0.5	0.5	0.5	0.5	0.75	0	0.5	0	0.5	1.25	0.5	0	0	0	1	0.5	0.75	1	0.5	0.5	0	0	0
	I&T	0	0	0.75	1	0.5	1	0.5	0	0	0	0	1.5	0	0	0	0	0.75	0.75	0	0.5	0.75	0.75	0	0	0
	LOCO	0	0	0.5	0.75	0.5	0.75	0	0	0	0	0	1.5	0	0	0	0	0.5	0.75	0	1	1	0.75	0	0	0

STATISTICAL APPROACH DETAILS – Standard Regression Approach

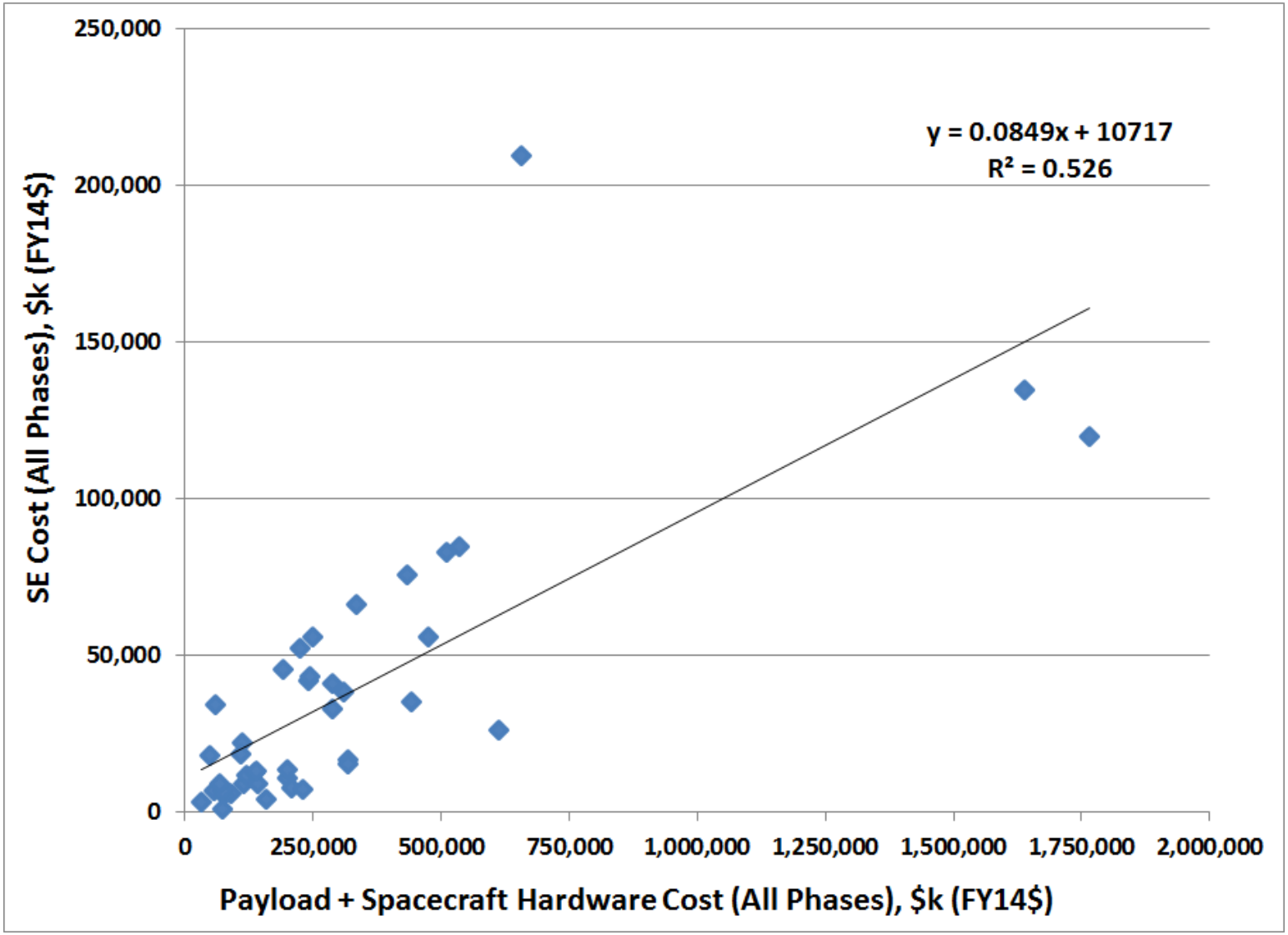
Standard Regression Approach Results
Total PM/SE/MA/I&T for Phases B/C/D



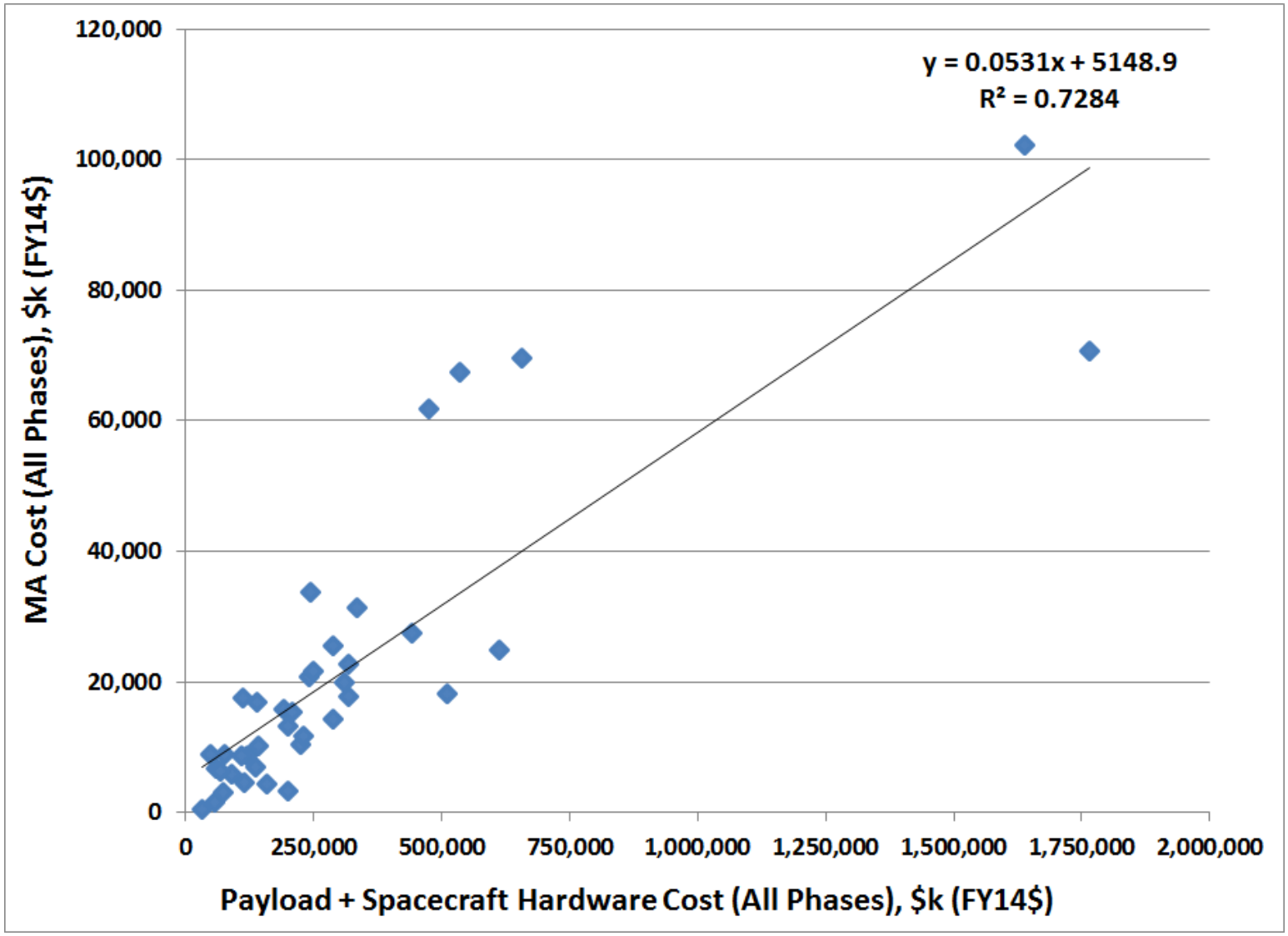
Standard Regression Approach Results
Total PM for Phases B/C/D



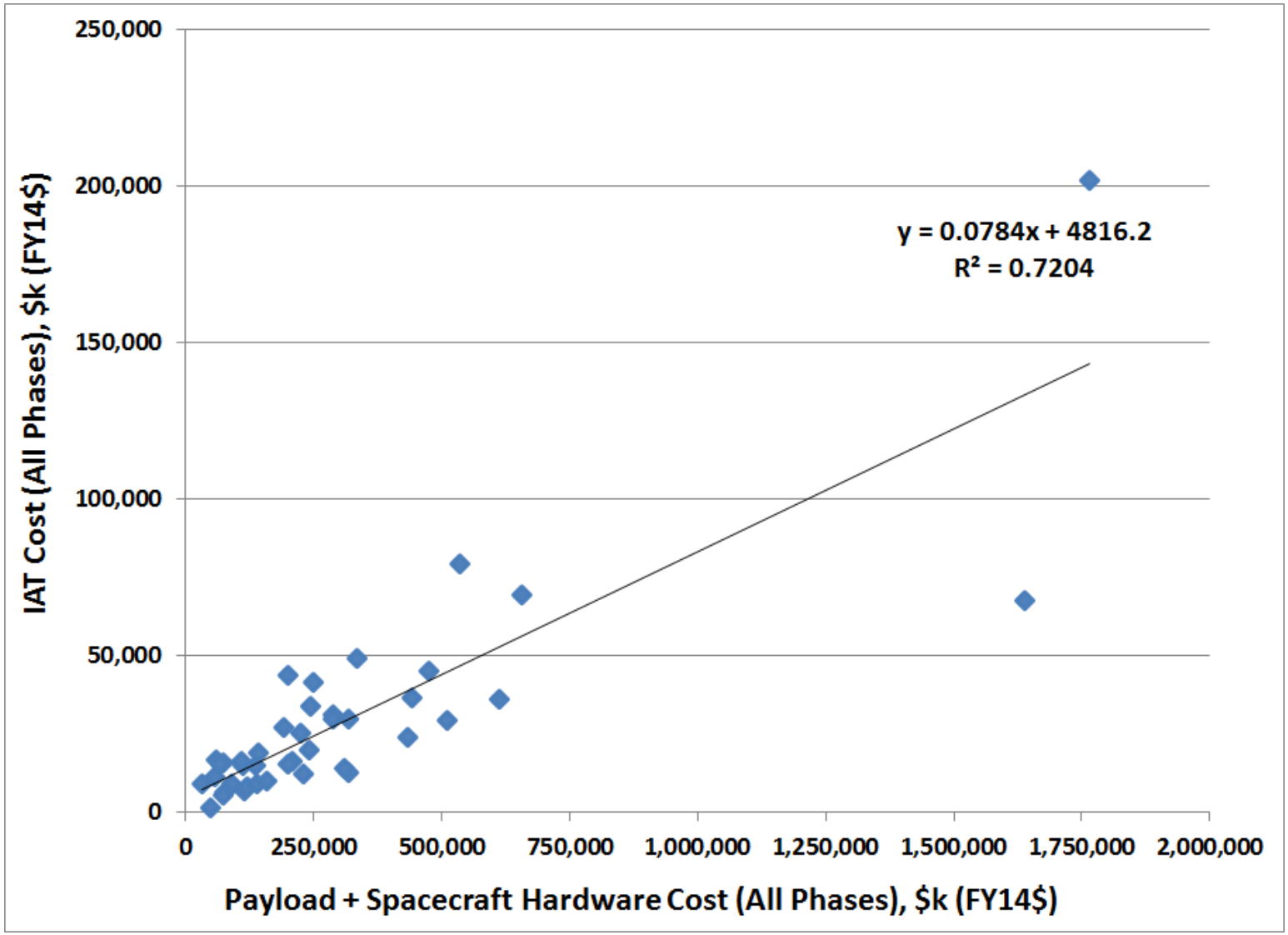
Standard Regression Approach Results
Total SE for Phases B/C/D



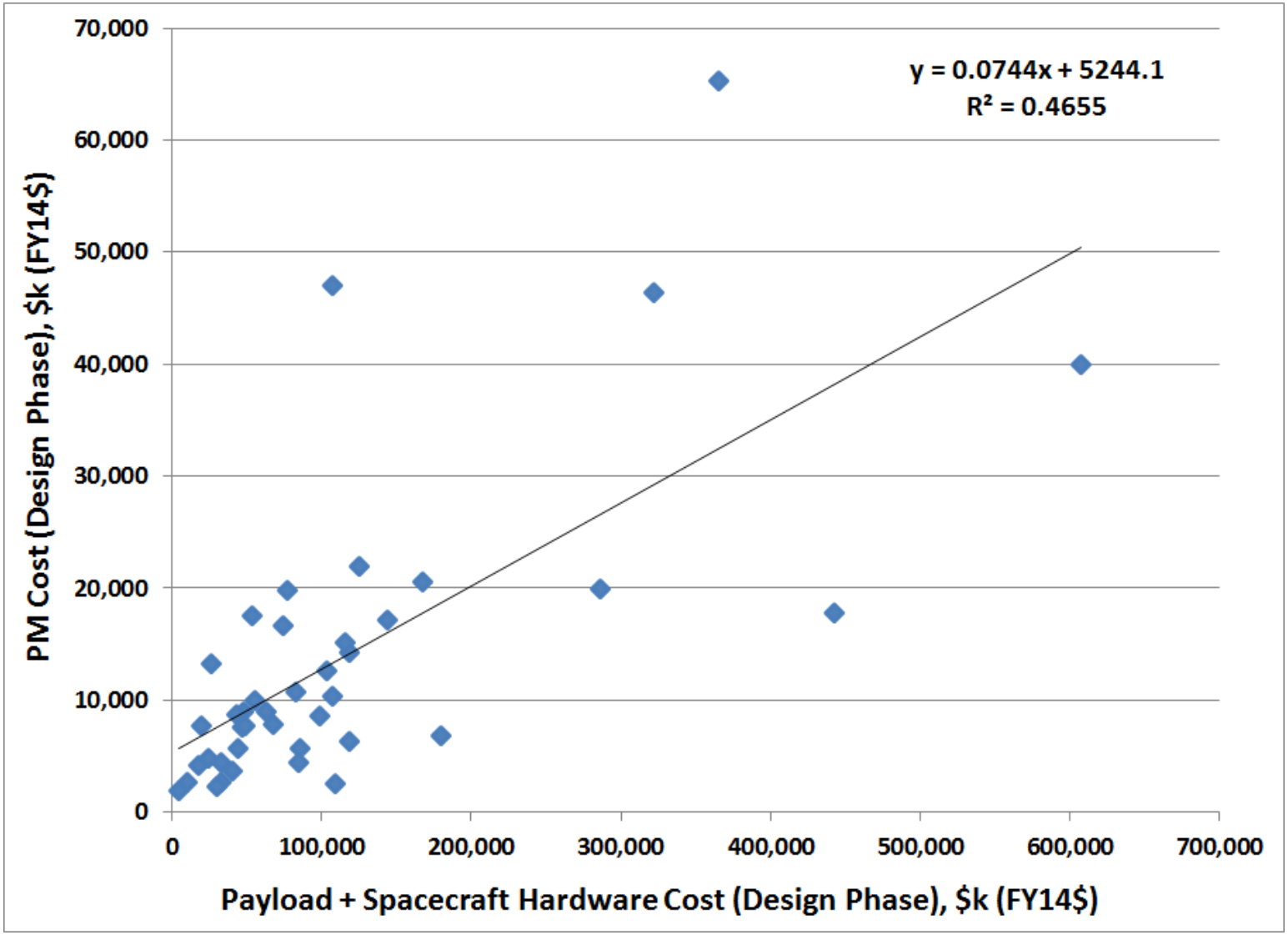
Standard Regression Approach Results
Total MA for Phases B/C/D



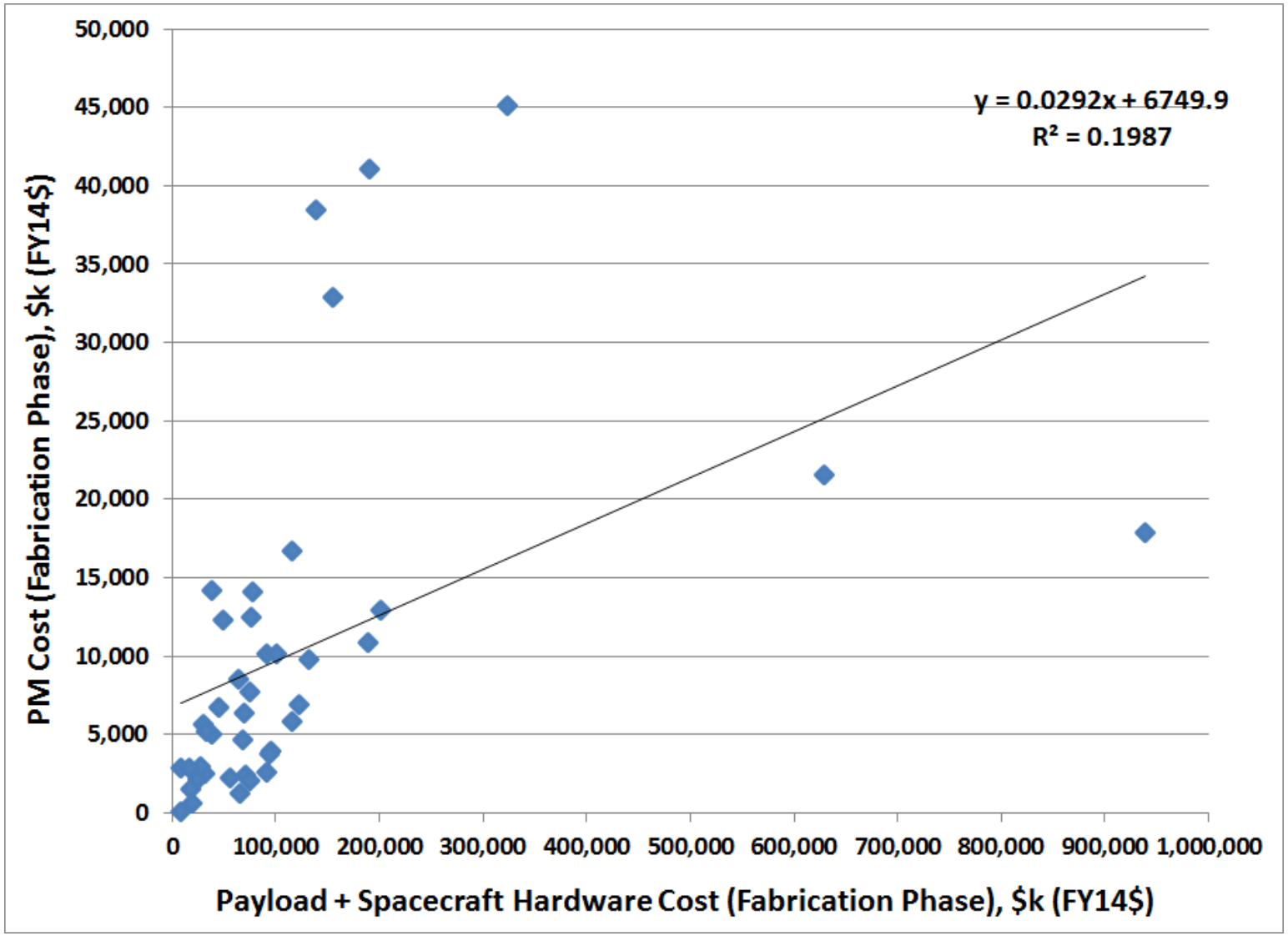
Standard Regression Approach Results
Total I&T for Phases B/C/D



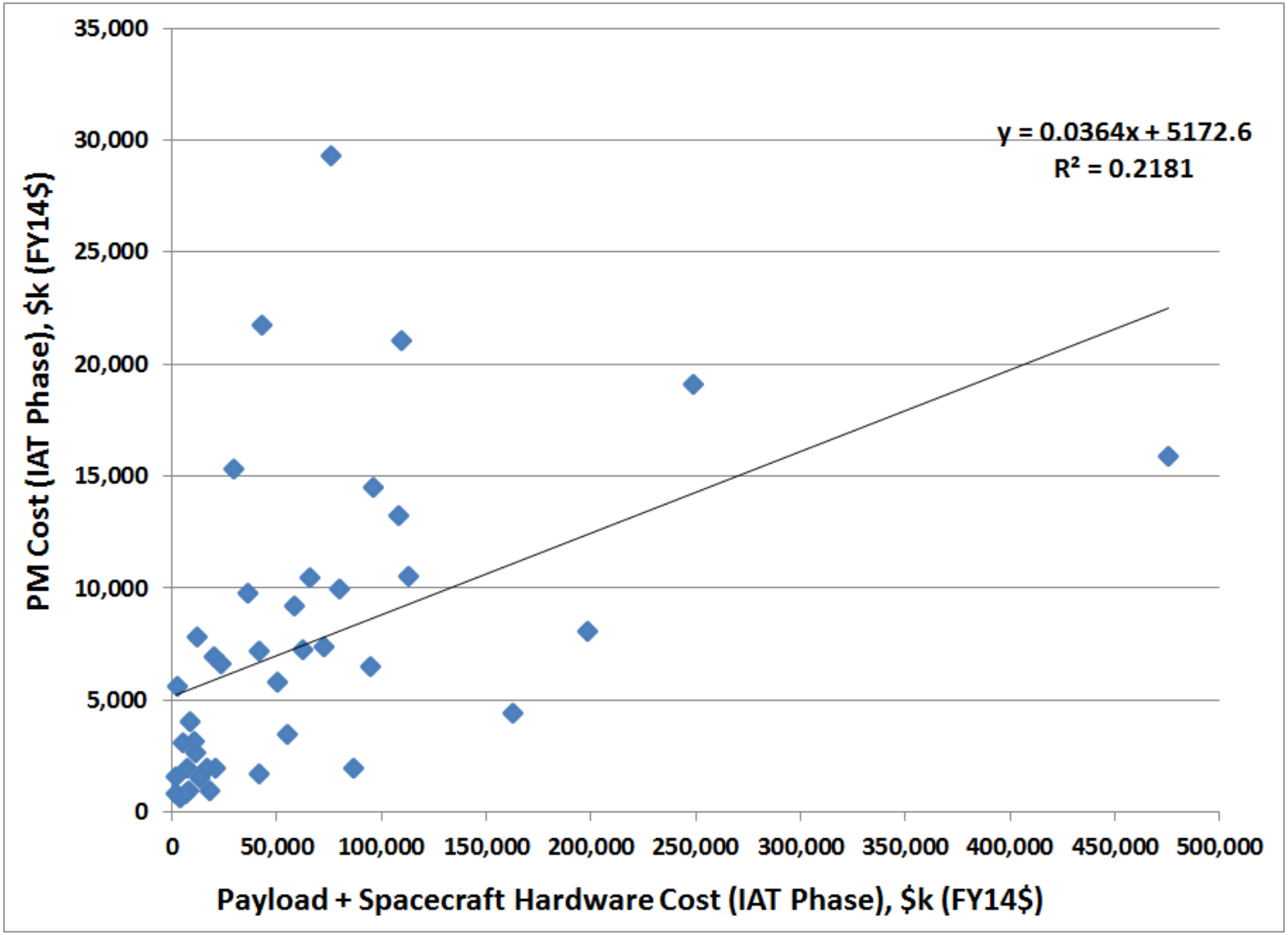
Standard Regression Approach Results – PM for the Design Phase



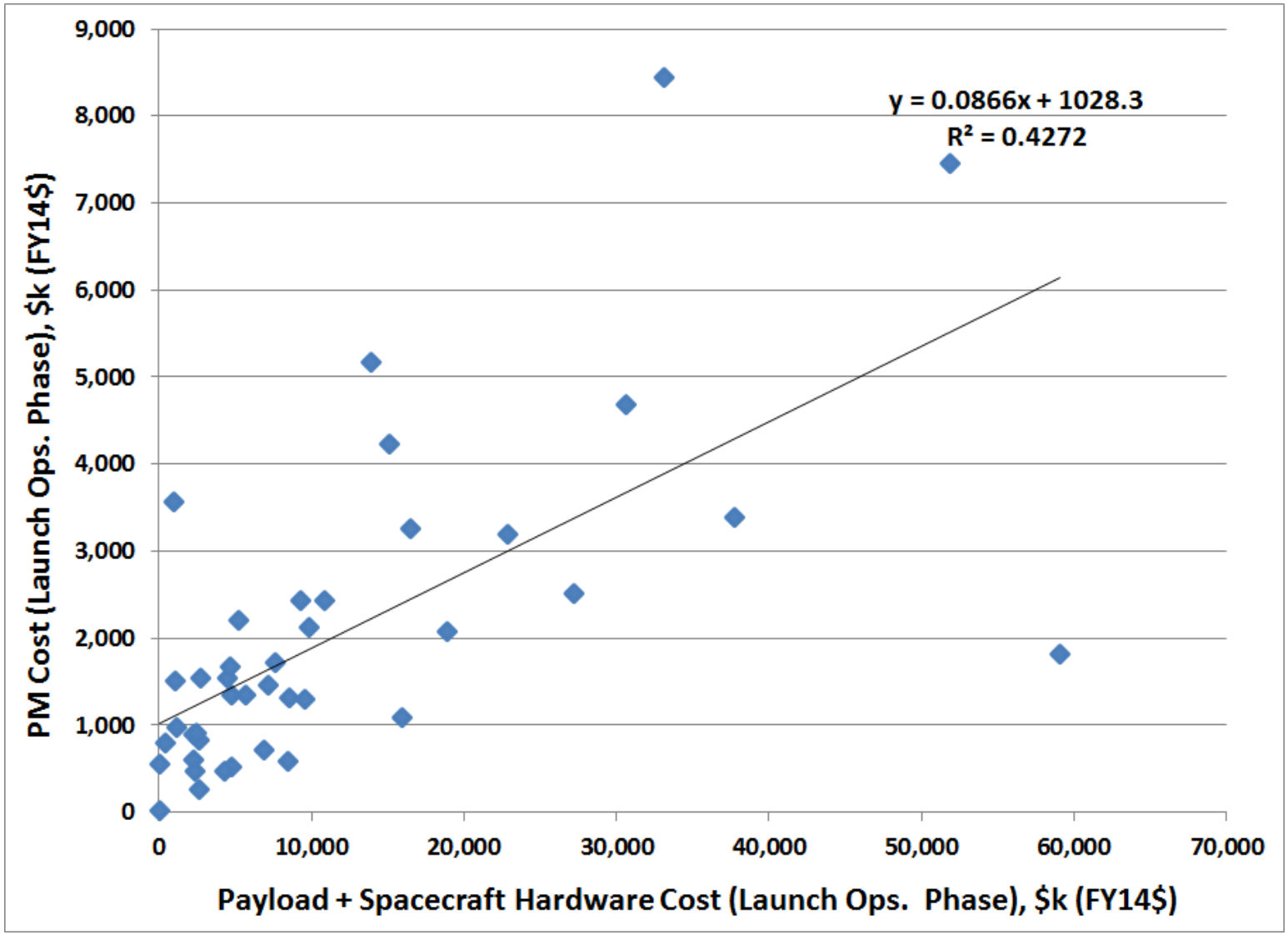
Standard Regression Approach Results – PM for the Fabrication Phase



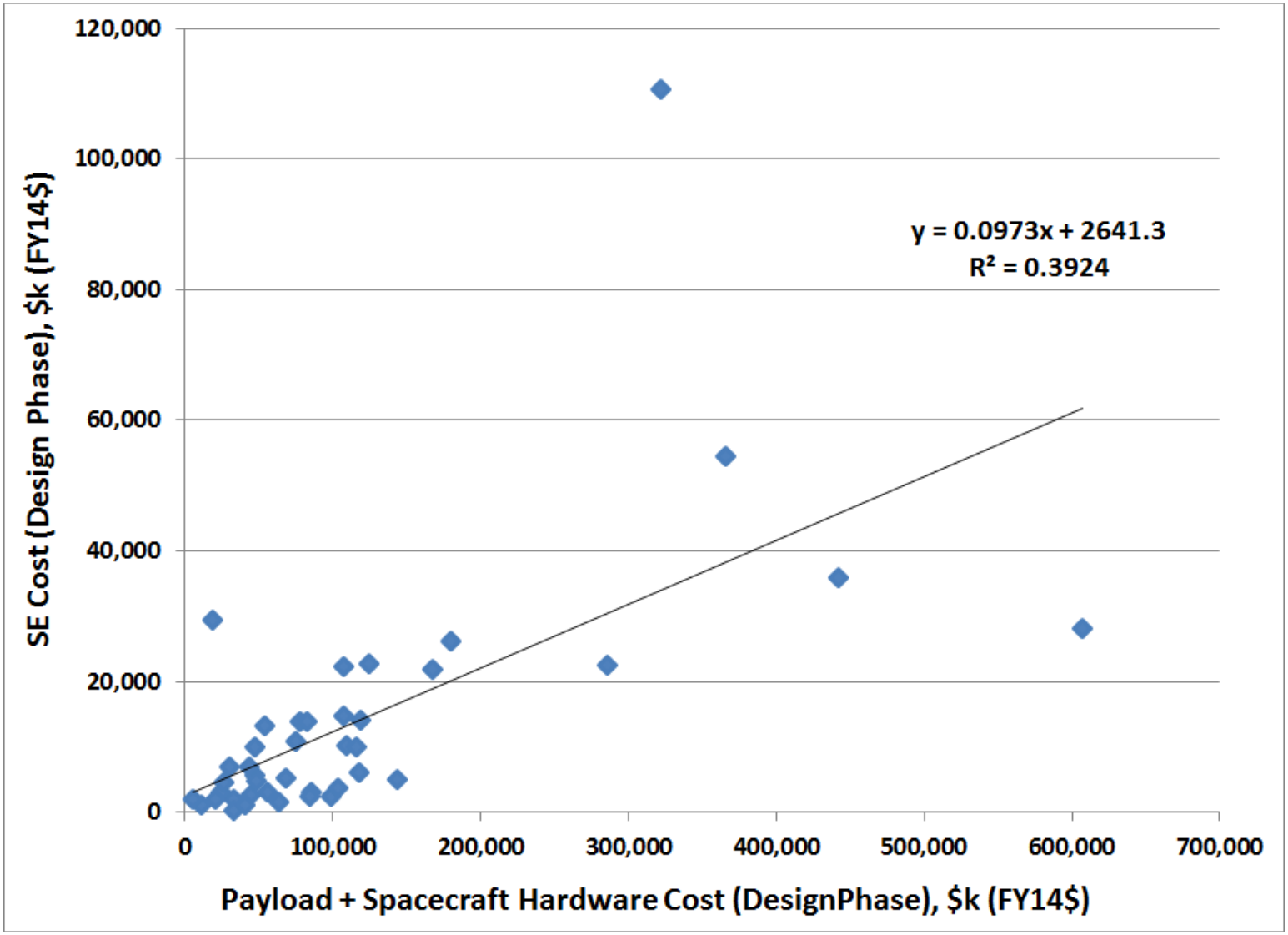
Standard Regression Approach Results – PM for the I&T Phase



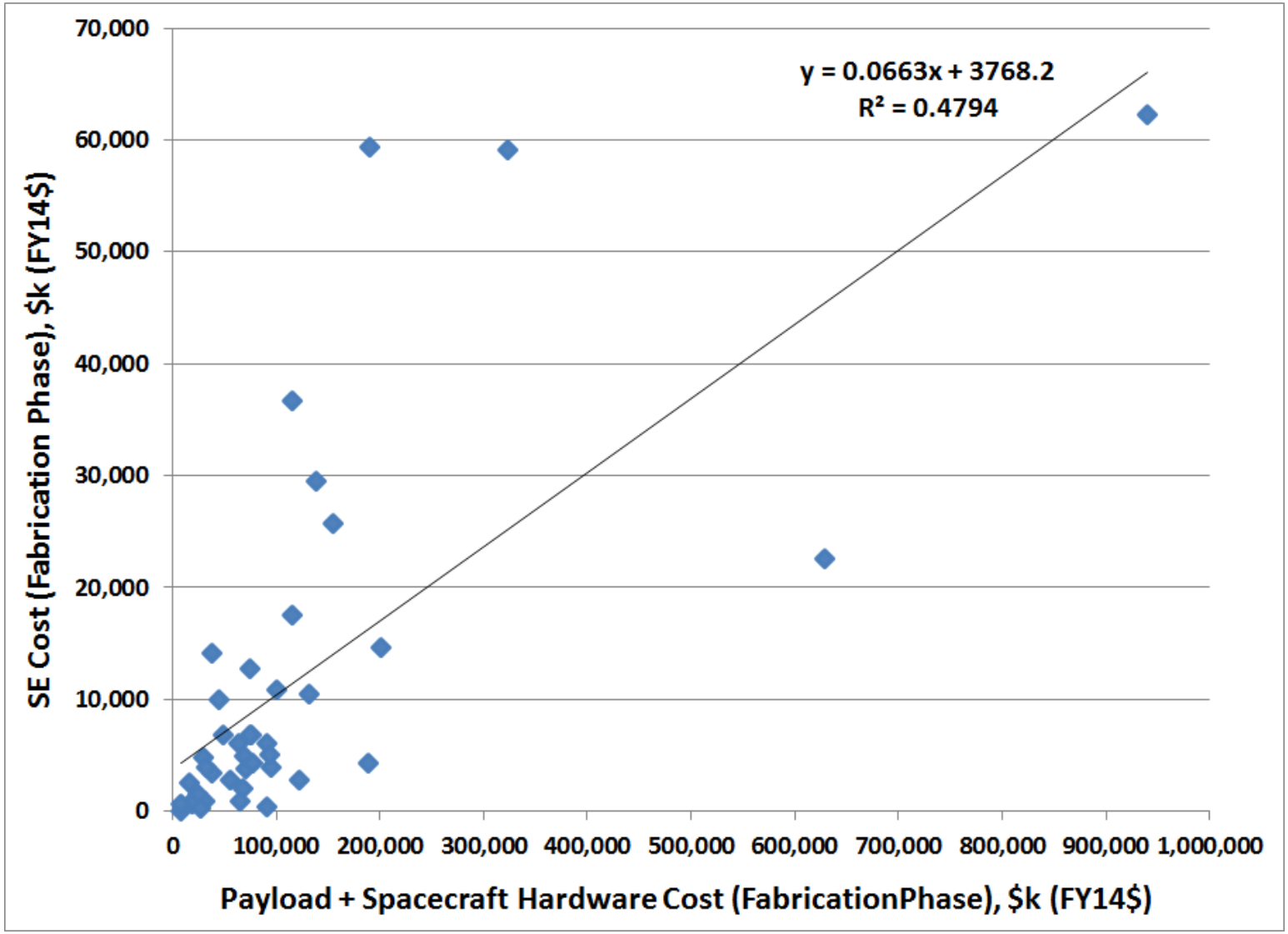
Standard Regression Approach Results – PM for the LOCO Phase



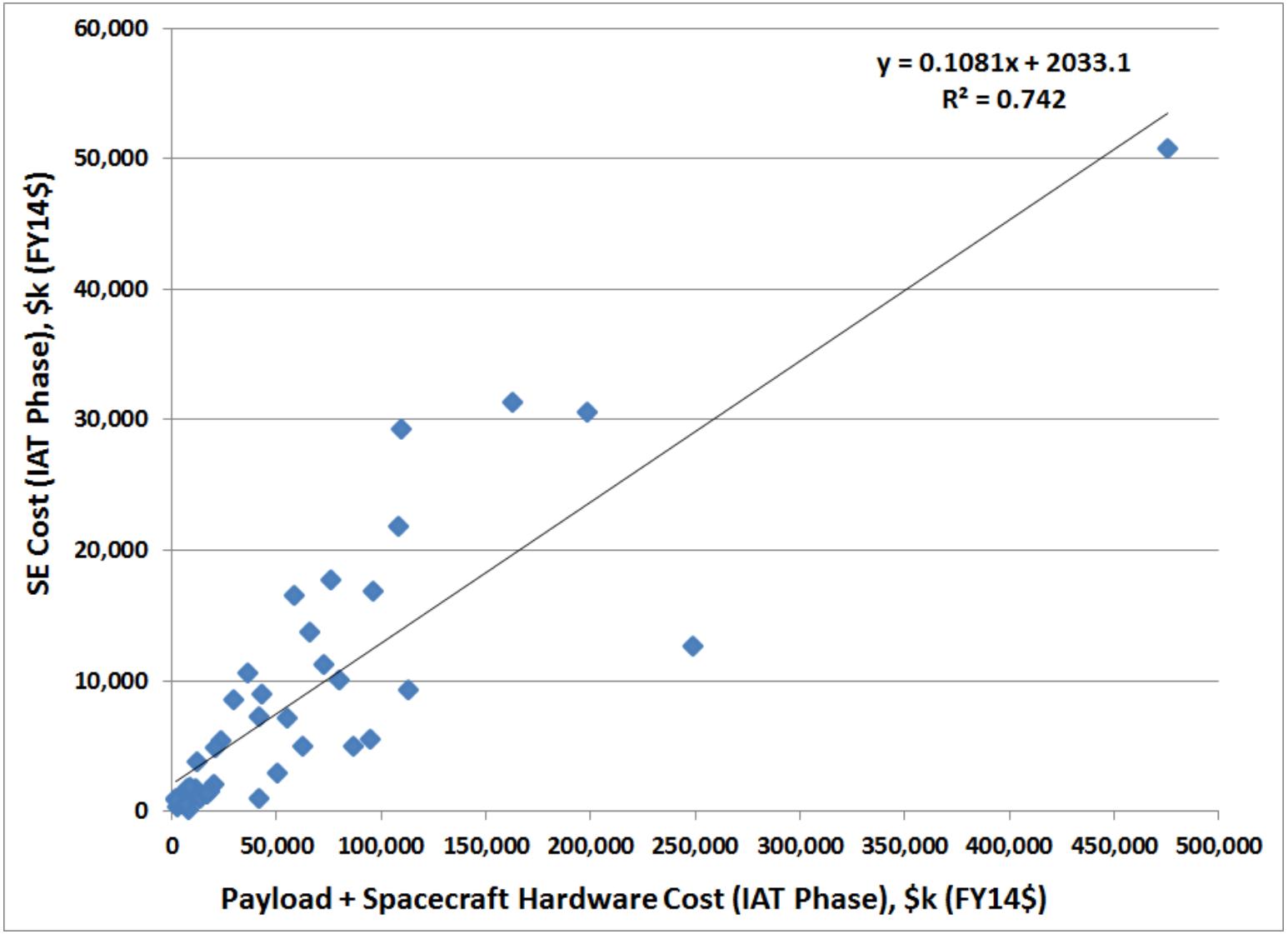
Standard Regression Approach Results – SE for the Design Phase



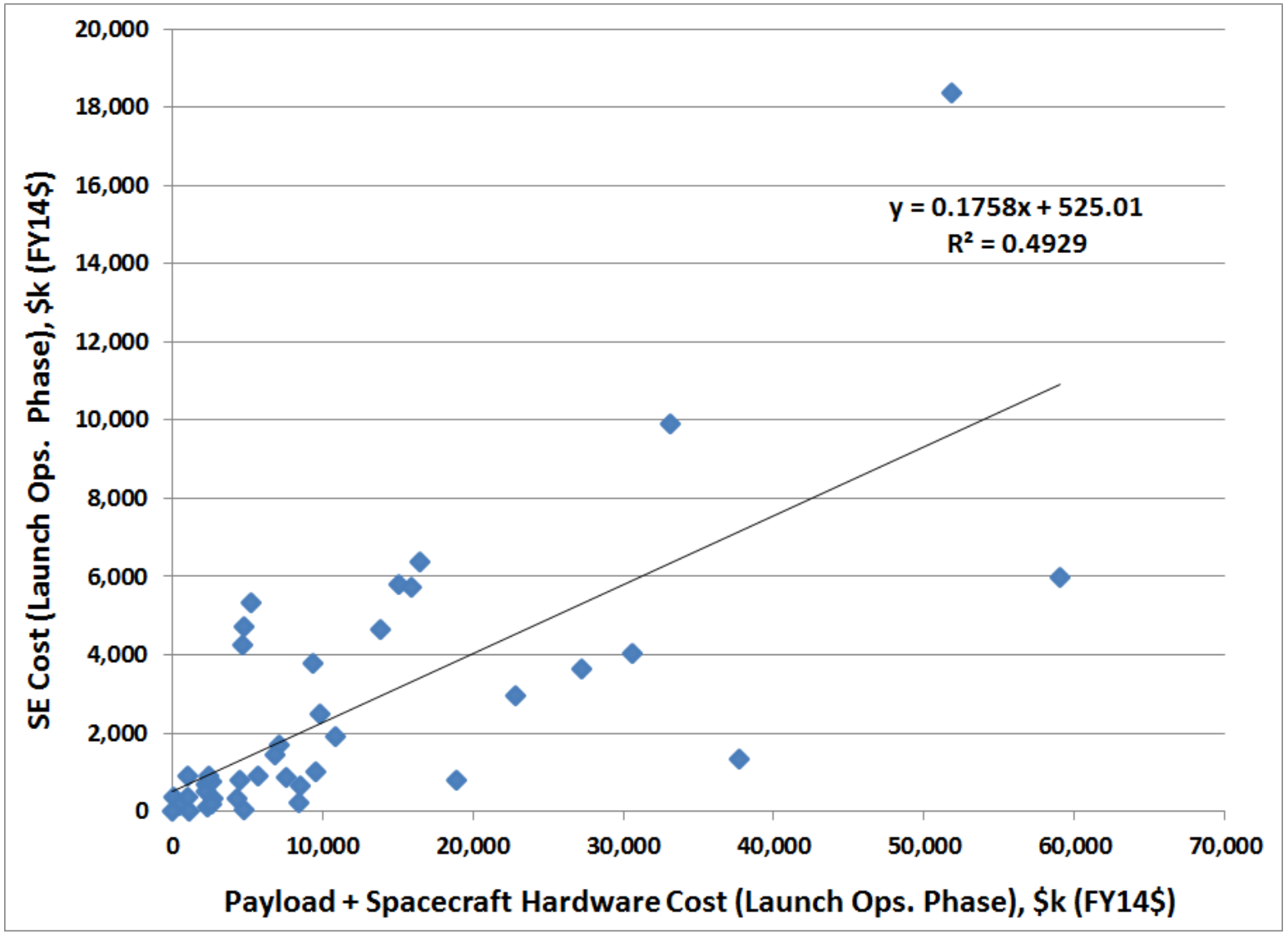
Standard Regression Approach Results – SE for the Fabrication Phase



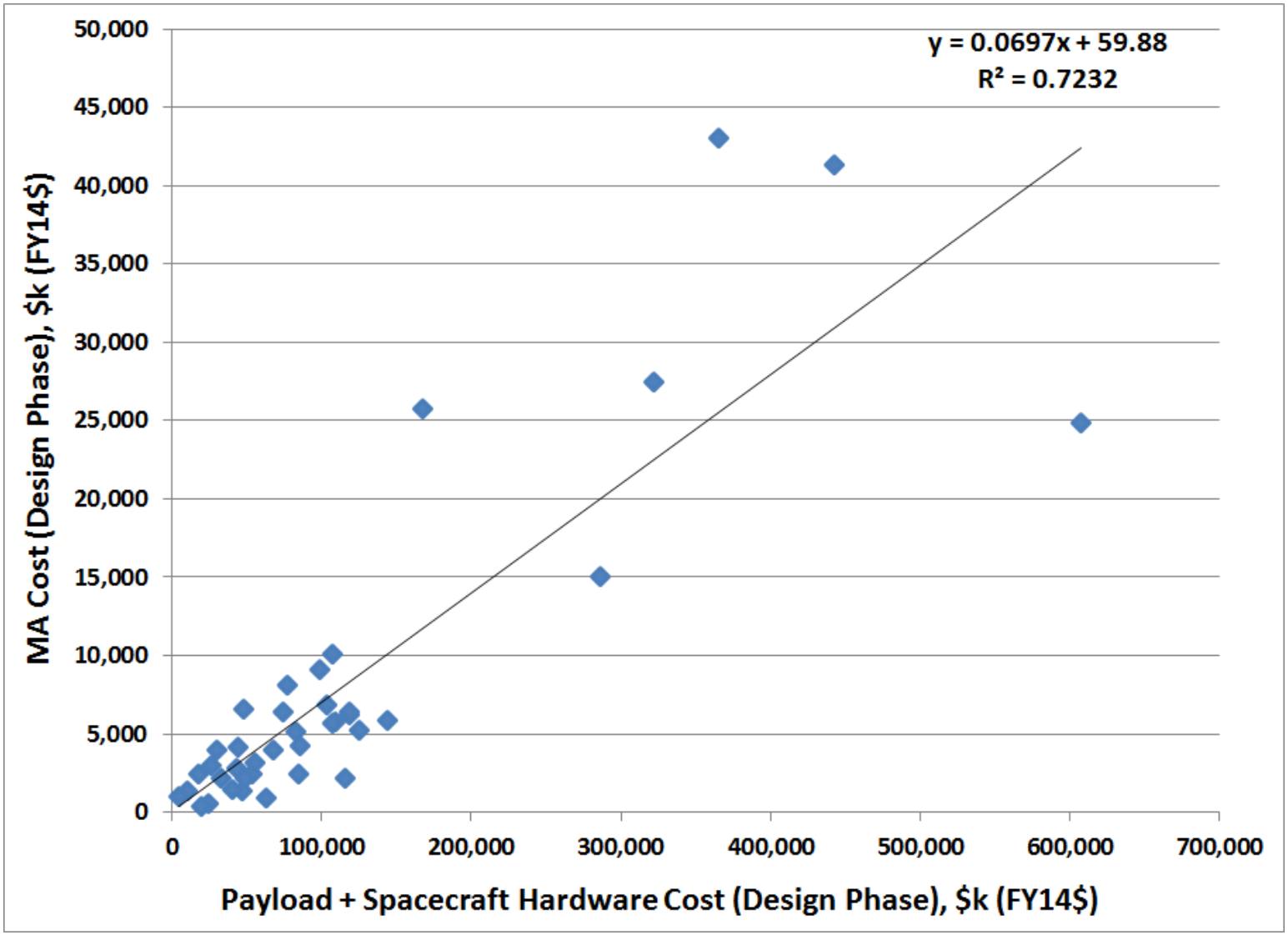
Standard Regression Approach Results – SE for the I&T Phase



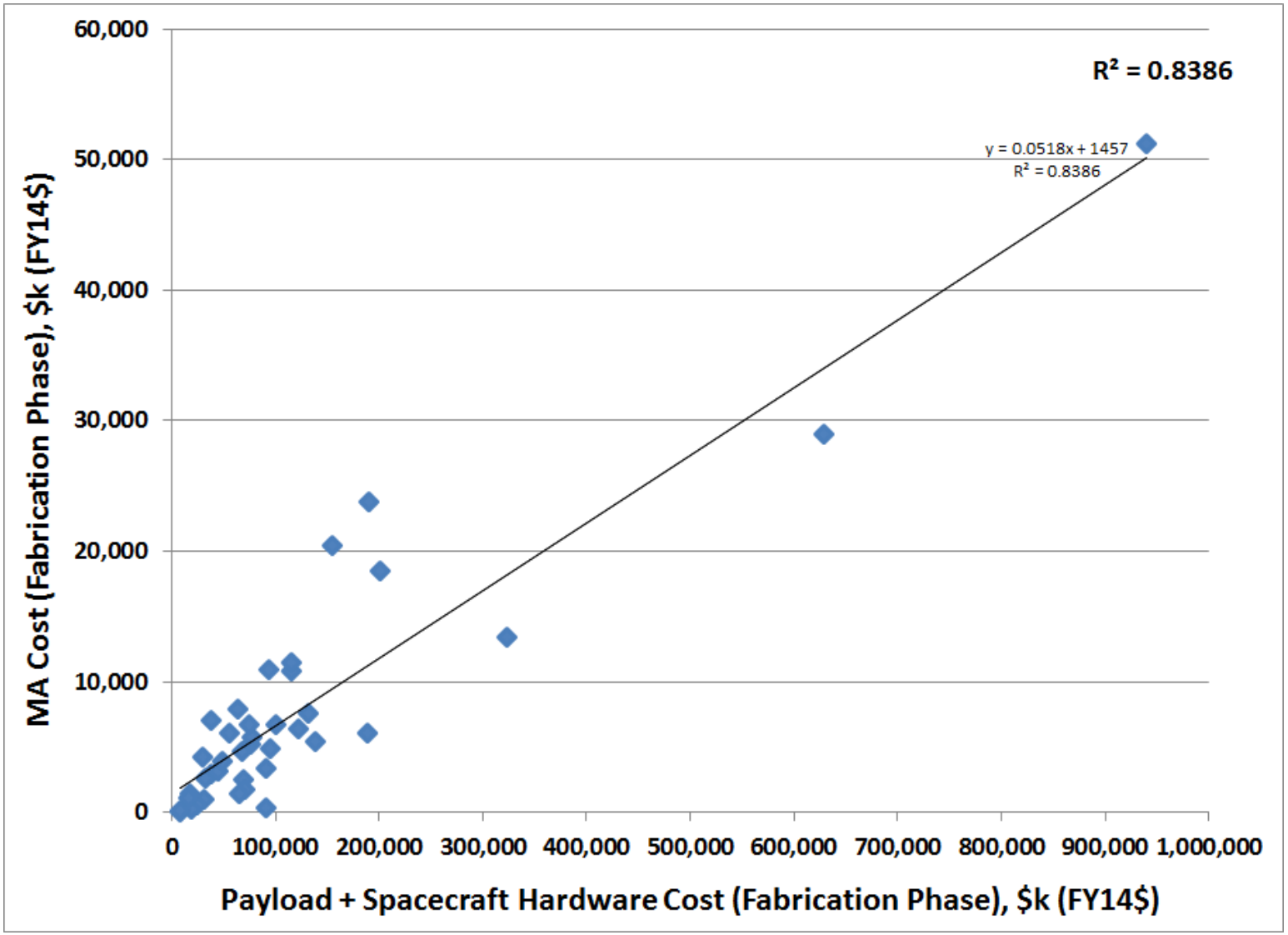
Standard Regression Approach Results – SE for the LOCO Phase



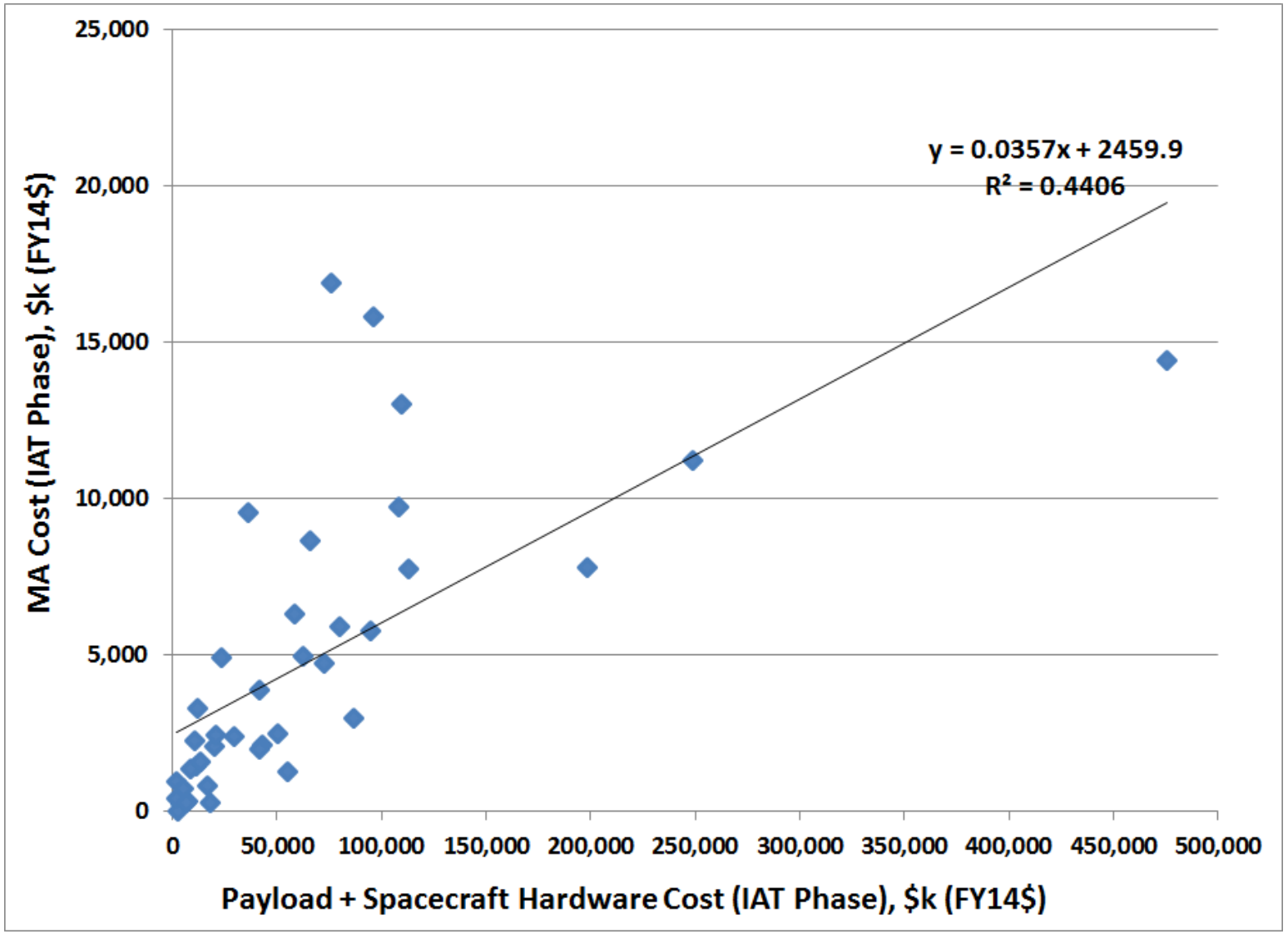
Standard Regression Approach Results – MA for the Design Phase



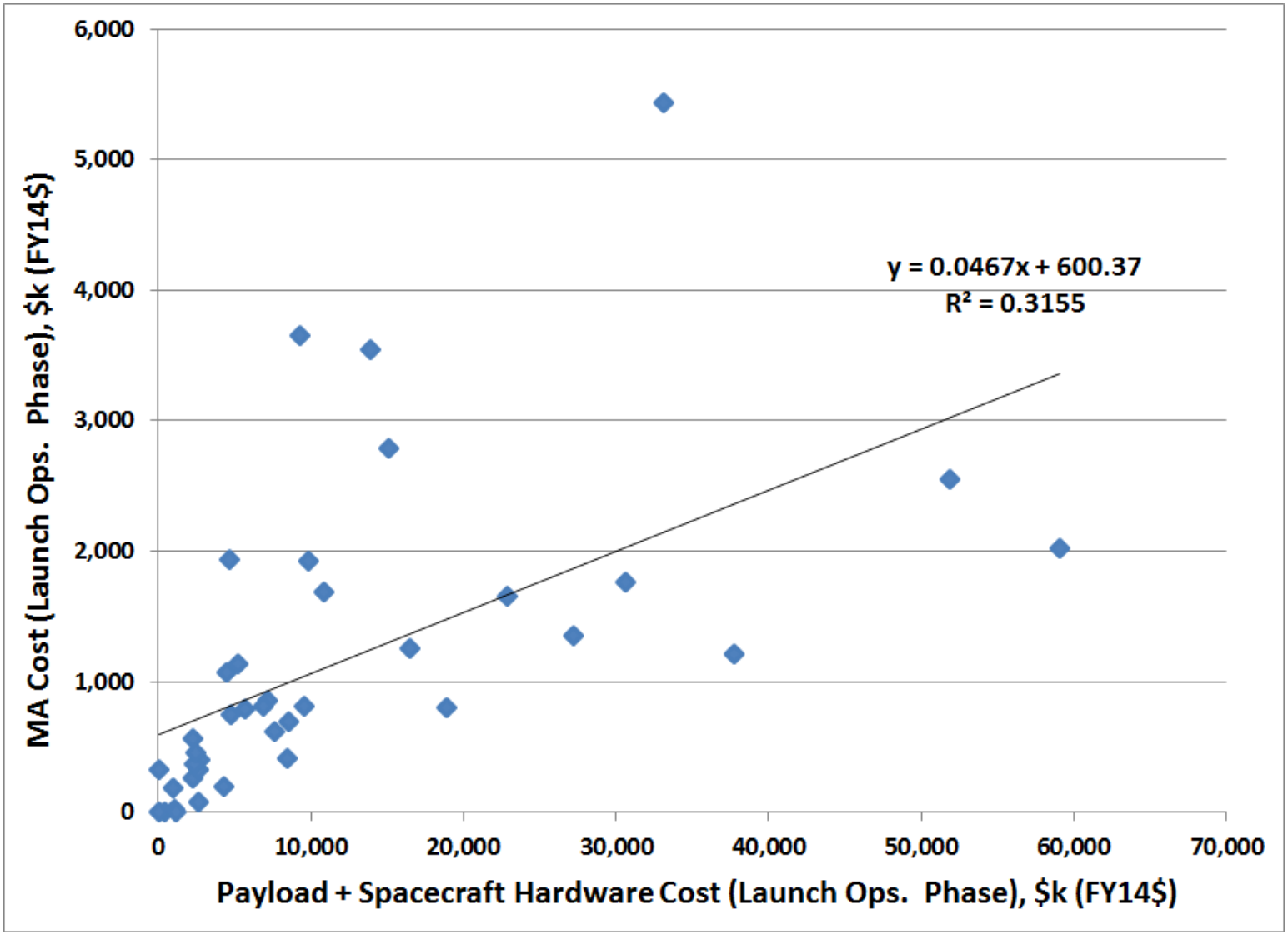
Standard Regression Approach Results – MA for the Fabrication Phase



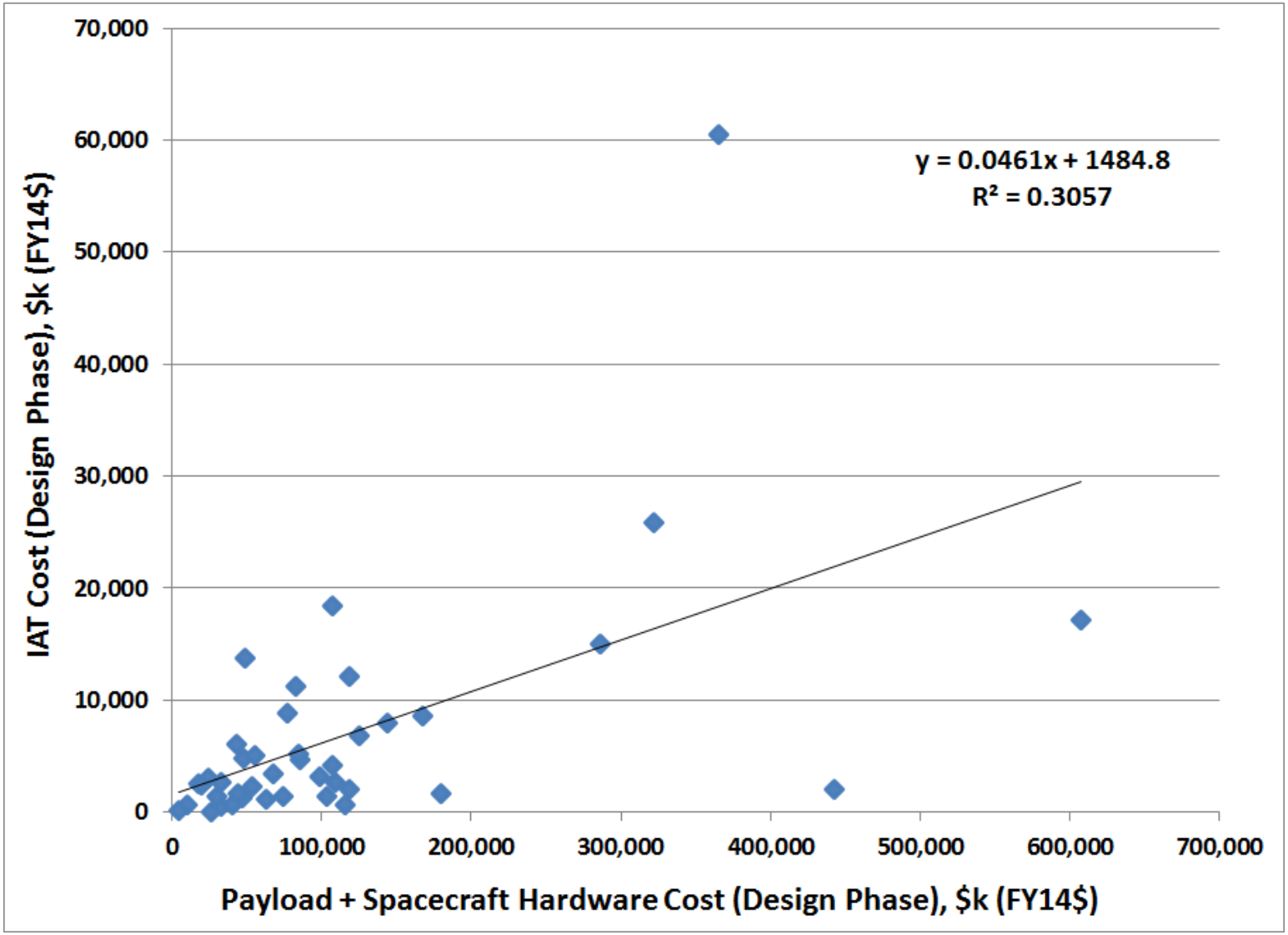
Standard Regression Approach Results – MA for the I&T Phase



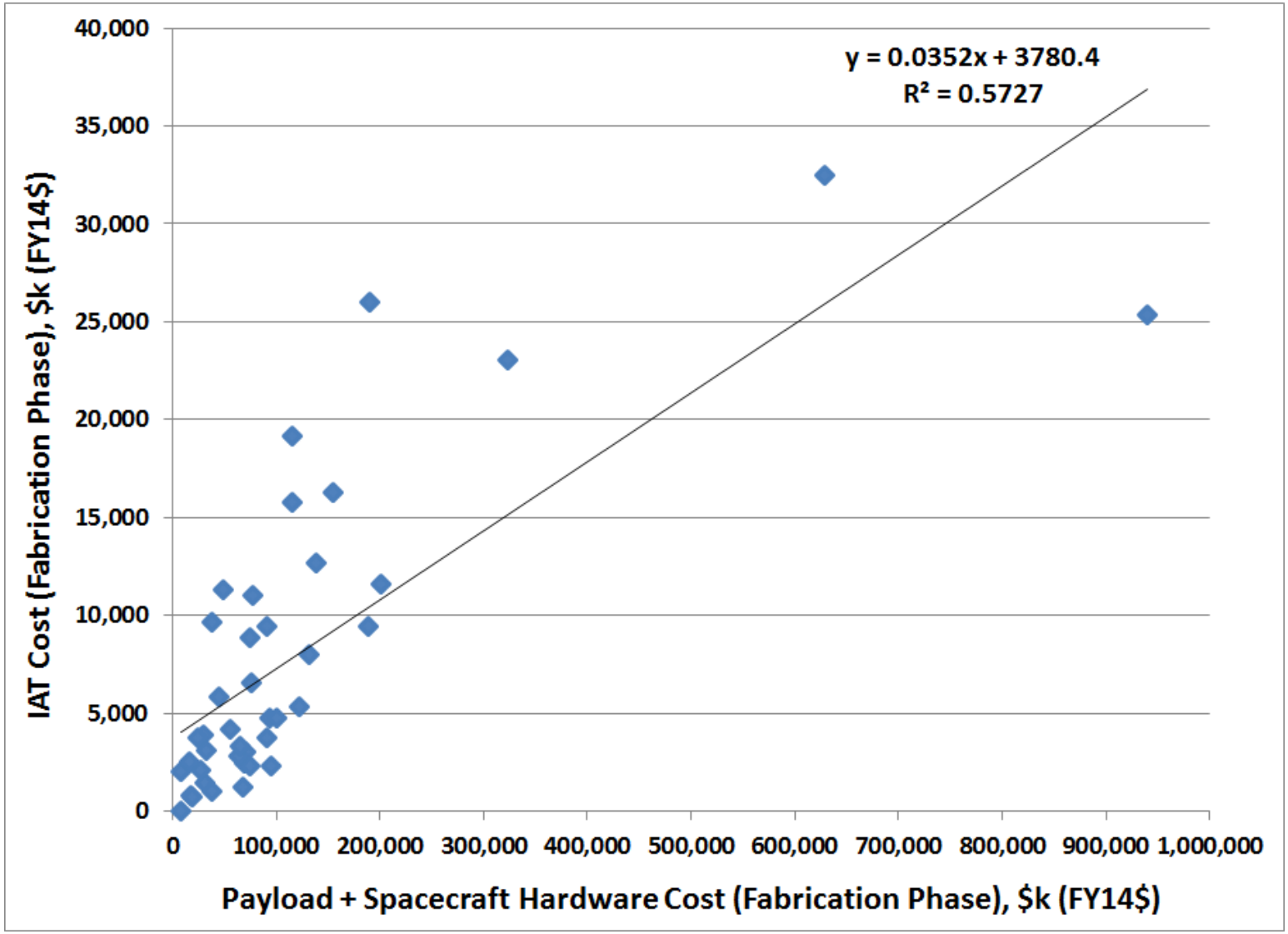
Standard Regression Approach Results – MA for the LOCO Phase



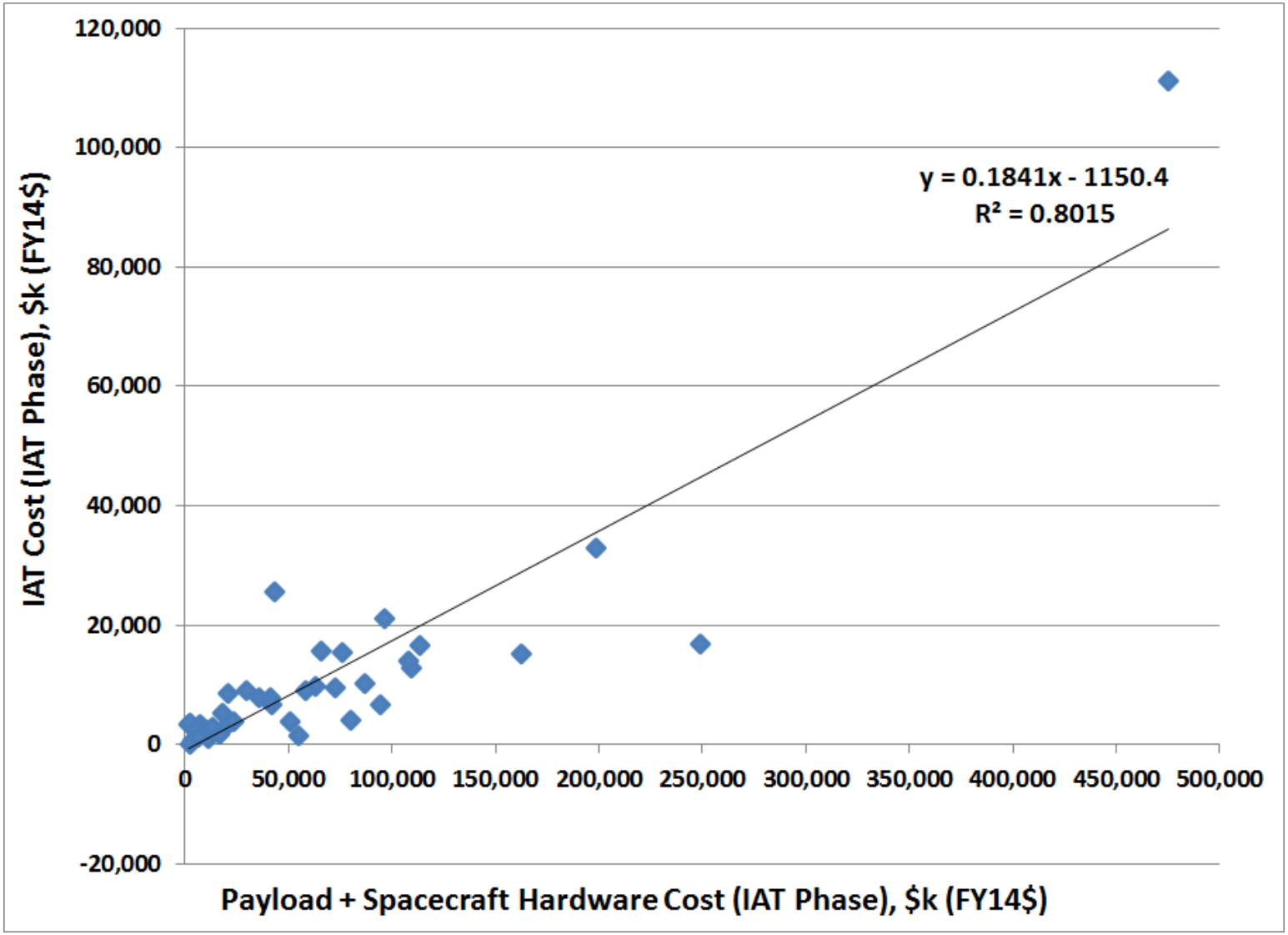
Standard Regression Approach Results – I&T for the Design Phase



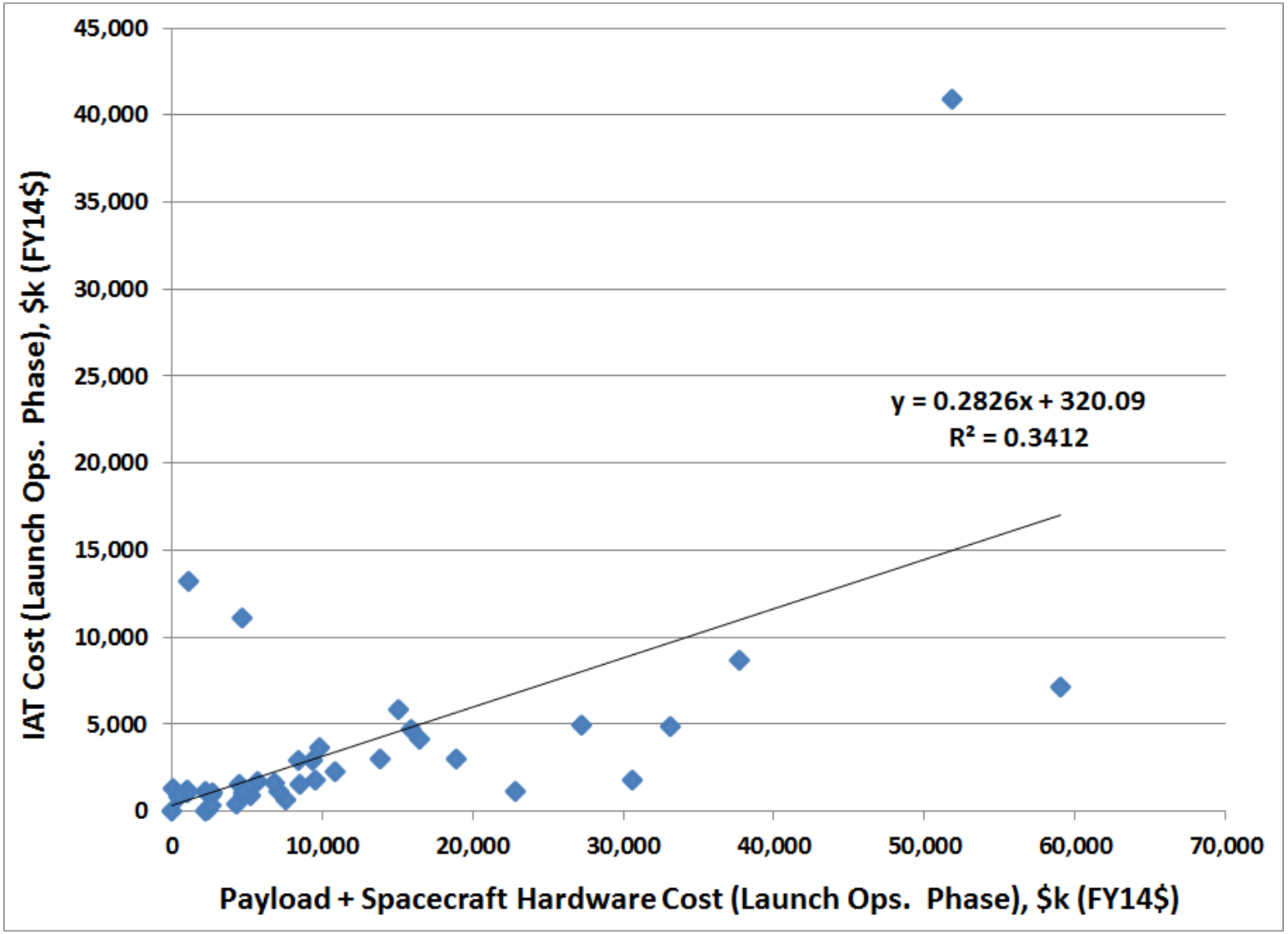
Standard Regression Approach Results – I&T for the Fabrication Phase



Standard Regression Approach Results – I&T for the I&T Phase



Standard Regression Approach Results – I&T for the LOCO Phase



STATISTICAL APPROACH DETAILS – PCA Approach

Data Set Correlation Matrix

Engineering Cost Office

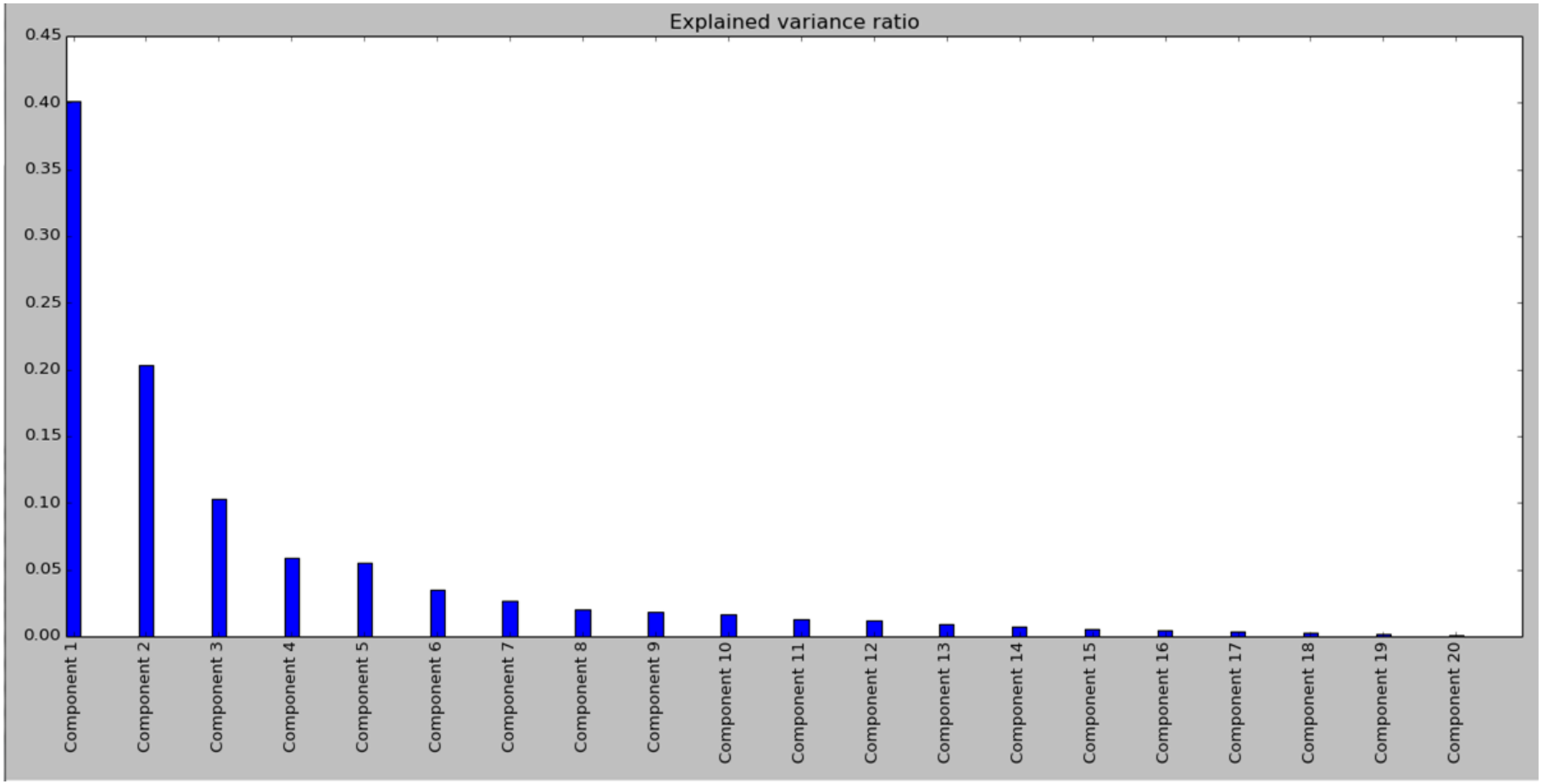
	LN $k-FY14 Per Month	LN DIRECTED or AO	LN MISSION RISK CLASS	LN MISSION DESTINATION	LN FLIGHT SYSTEM TYPE	LN LEAD ORGANIZATION	LN FLIGHT SYSTEM ORGANIZATION	LN PAYLOAD ORG.	LN FLIGHT SYSTEM LEAD ORG. EXPERIENCE	LN PAYLOAD LEAD ORG. EXPERIENCE	LN FLIGHT SYSTEM MASS	LN FLIGHT SYSTEM POWER	LN FLIGHT SYSTEM HERITAGE & TRL	LN PARTS RATING	LN # OF KEY SPACECRAFT CONTRACTORS	LN PAYLOAD MASS	LN PAYLOAD POWER	LN # OF PAYLOAD ELEMENTS	LN # OF KEY PAYLOAD CONTRACTORS	LN IN-HOUSE SCOPE	LN INTERNATIONAL PARTICIPATION (HW)
LN $k-FY14 Per Month	1																				
LN DIRECTED or AO	0.25	1																			
LN MISSION RISK CLASS	-0.6	-0.5	1																		
LN MISSION DESTINATION	0.55	-0	-0.2	1																	
LN FLIGHT SYSTEM TYPE	0.16	0.07	0.09	0.37	1																
LN LEAD ORGANIZATION	0.66	0.29	-0.4	0.22	0.13	1															
LN FLIGHT SYSTEM ORGANIZATION	0.34	-0	0.06	0.09	0.12	0.27	1														
LN PAYLOAD ORG.	0.39	0.14	-0.2	-0	0.05	0.52	0.39	1													
LN FLIGHT SYSTEM LEAD ORG. EXPERIENCE	0.21	0.14	-0.1	0	-0.2	0.3	0.31	0.12	1												
LN PAYLOAD LEAD ORG. EXPERIENCE	0.63	0.2	-0.5	0.34	-0.1	0.26	0.33	0.15	0.49	1											
LN FLIGHT SYSTEM MASS	0.74	0.38	-0.5	0.48	0.11	0.55	0.07	0.3	0.07	0.48	1										
LN FLIGHT SYSTEM POWER	0.6	0.21	-0.4	0.06	-0.1	0.57	0.08	0.3	0.06	0.32	0.72	1									
LN FLIGHT SYSTEM HERITAGE & TRL	0.02	-0.1	0.01	-0	-0.2	0.02	0.3	0.02	0.44	0.38	-0.1	-0.2	1								
LN PARTS RATING	0.76	0.19	-0.6	0.54	0.22	0.52	-0	0.34	0.03	0.55	0.71	0.58	-0.2	1							
LN # OF KEY SPACECRAFT CONTRACTORS	0.43	0.04	-0.1	0.46	0.27	0.16	0.18	0.3	-0.2	0.06	0.38	0.19	-0.1	0.33	1						
LN PAYLOAD MASS	0.27	0.3	-0.3	-0.1	-0.1	0.44	0.11	0	0.43	0.2	0.28	0.31	0.14	0.19	-0.4	1					
LN PAYLOAD POWER	0.39	0.42	-0.4	-0.1	-0.1	0.46	0.2	0.28	0.36	0.41	0.54	0.55	0.12	0.34	-0	0.7	1				
LN # OF PAYLOAD ELEMENTS	0.08	0.06	-0.1	0.31	0.12	-0.4	-0.3	-0.2	-0.2	0.15	0.18	-0.2	-0.2	0.12	0.23	-0.4	-0.2	1			
LN # OF KEY PAYLOAD CONTRACTORS	-0.1	-0.1	-0.1	0.12	-0.1	-0.2	-0.3	-0.2	-0.2	-0.2	-0	-0.1	-0.3	-0.1	-0.1	-0.1	-0.3	0.58	1		
LN IN-HOUSE SCOPE	0.34	0.18	-0.3	0.33	0.16	0.1	-0.3	0.03	0.03	0.3	0.49	0.16	-0.1	0.47	0.34	-0.1	0.08	0.47	0.08	1	
LN INTERNATIONAL PARTICIPATION (HW)	-0	0.15	-0.1	-0.2	-0.1	0.13	-0	0.12	0.23	-0.1	-0.1	0.09	-0.2	-0.1	0.03	-0	0.03	-0.2	-0.3	-0.1	1

Results of the PCA

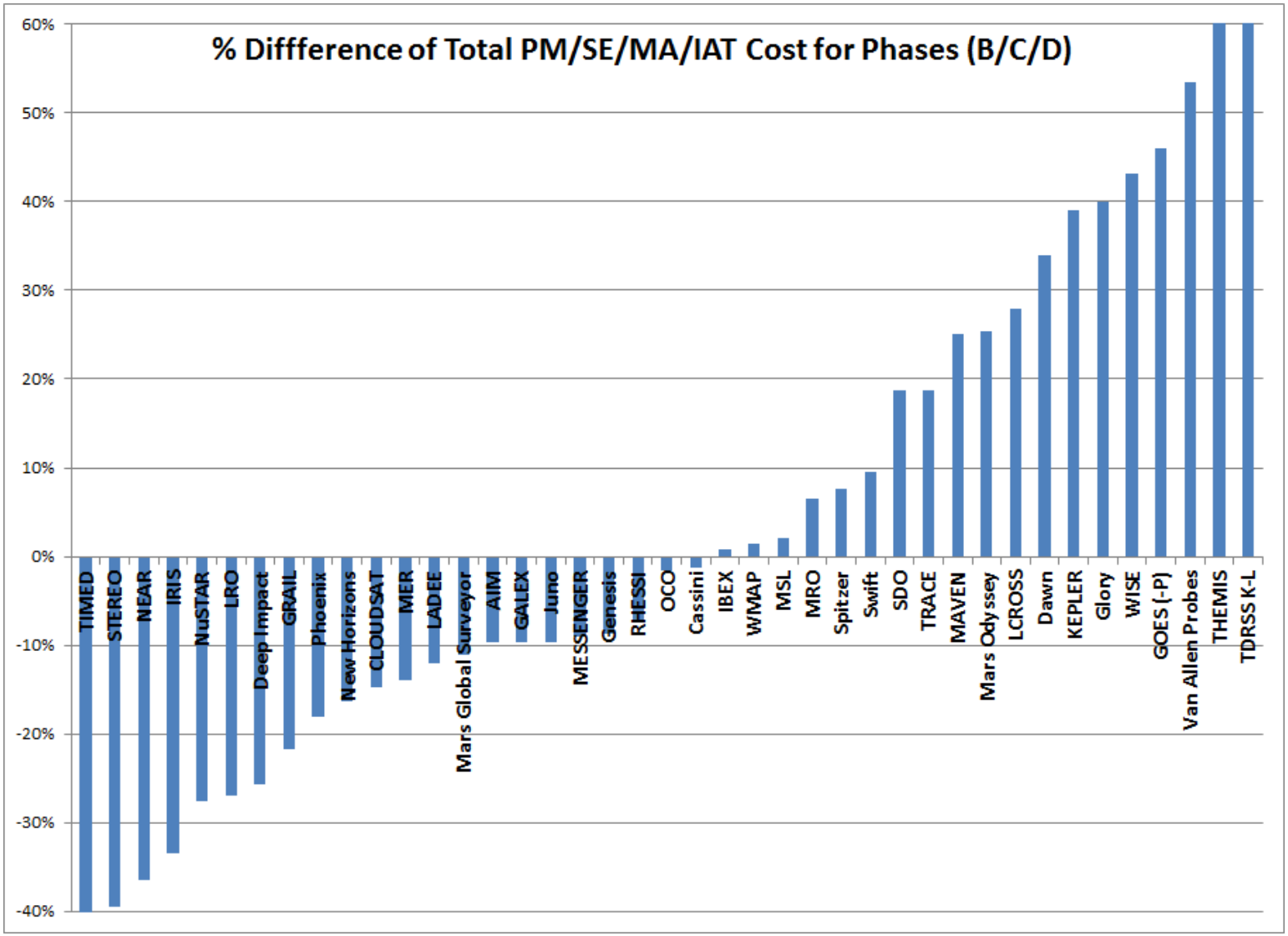
Engineering Cost Office

	Explained variance ratio			LN DIRECTED or AO	LN MISSION RISK CLASS	LN MISSION DESTINATION	LN FLIGHT SYSTEM TYPE	LN LEAD ORGANIZATION	LN FLIGHT SYSTEM ORGANIZATION	LN PAYLOAD ORG.	LN FLIGHT SYSTEM LEAD ORG. EXPERIENCE	LN PAYLOAD LEAD ORG. EXPERIENCE	LN FLIGHT SYSTEM MASS	LN FLIGHT SYSTEM POWER	LN FLIGHT SYSTEM HERITAGE & TRL	LN PARTS RATING	LN # OF KEY SPACECRAFT CONTRACTORS	LN PAYLOAD MASS	LN PAYLOAD POWER	LN # OF PAYLOAD ELEMENTS	LN # OF KEY PAYLOAD CONTRACTORS	LN IN-HOUSE SCOPE	LN INTERNATIONAL PARTICIPATION (HW)
Component 1	40%		Component 1	-0.077	0.112	-0.049	-0.004	-0.151	-0.023	-0.089	-0.038	-0.044	-0.432	-0.472	0.008	-0.127	-0.003	-0.467	-0.542	0.064	0.044	-0.040	-0.010
Component 2	20%		Component 2	0.004	-0.104	0.255	0.057	0.034	-0.023	-0.012	-0.066	0.035	0.430	0.289	-0.112	0.176	0.099	-0.422	-0.253	0.505	0.276	0.136	0.005
Component 3	10%		Component 3	0.084	-0.050	0.057	0.000	-0.162	-0.069	-0.341	0.007	-0.002	-0.010	-0.389	-0.023	-0.033	-0.096	0.525	0.063	0.420	0.461	0.057	-0.076
Component 4	6%		Component 4	-0.115	0.010	-0.358	-0.242	-0.010	-0.048	-0.206	-0.070	-0.090	-0.226	0.589	-0.136	-0.092	-0.097	0.138	-0.301	-0.129	0.391	-0.160	0.042
Component 5	6%		Component 5	0.006	0.046	-0.487	-0.186	-0.248	-0.045	0.100	-0.030	0.005	-0.119	0.034	-0.016	-0.144	-0.019	-0.349	0.562	0.421	-0.005	-0.030	-0.007
Component 6	3%		Component 6	-0.114	-0.152	-0.091	-0.013	0.301	0.183	0.778	0.051	-0.039	-0.089	-0.137	-0.018	-0.007	-0.061	0.148	-0.104	0.154	0.304	-0.185	-0.091
Component 7	3%		Component 7	0.438	-0.274	-0.366	0.123	0.058	-0.219	0.125	-0.043	-0.096	0.052	-0.080	-0.289	-0.011	-0.072	0.107	-0.212	0.038	-0.177	0.348	0.445
Component 8	2%		Component 8	-0.050	0.195	-0.063	0.531	-0.225	-0.027	0.093	-0.425	-0.289	0.113	-0.017	-0.445	-0.049	0.004	0.002	0.078	-0.156	0.081	-0.081	-0.304
Component 9	2%		Component 9	0.231	0.039	-0.226	-0.336	-0.203	-0.078	0.126	-0.082	-0.009	0.519	-0.147	0.310	-0.207	-0.047	-0.047	-0.174	-0.284	0.140	0.143	-0.355
Component 10	2%		Component 10	-0.623	-0.034	-0.168	-0.017	-0.159	-0.180	0.074	-0.037	-0.004	0.084	0.055	0.075	0.093	-0.160	0.255	-0.234	0.258	-0.426	0.261	-0.177
Component 11	1%		Component 11	-0.179	0.625	-0.071	0.077	0.300	0.006	-0.027	0.246	-0.142	0.276	-0.052	-0.036	-0.448	0.027	0.041	-0.026	0.097	0.038	0.062	0.310
Component 12	1%		Component 12	0.281	-0.079	-0.241	0.224	0.094	0.335	-0.189	0.019	0.093	0.131	0.079	0.117	-0.174	0.044	0.112	-0.236	0.304	-0.361	-0.487	-0.209
Component 13	1%		Component 13	-0.093	-0.057	0.248	-0.460	-0.352	0.089	0.095	-0.110	-0.036	0.234	-0.124	-0.395	-0.093	-0.024	0.085	-0.053	0.005	-0.178	-0.417	0.330
Component 14	1%		Component 14	0.213	0.282	0.017	-0.396	0.387	-0.162	-0.051	0.061	0.050	-0.096	-0.059	-0.476	0.204	0.011	0.018	-0.014	0.095	-0.183	0.062	-0.454
Component 15	1%		Component 15	-0.284	-0.336	-0.146	-0.106	0.530	-0.165	-0.277	-0.422	-0.179	0.170	-0.251	0.072	-0.030	0.097	-0.119	0.133	-0.065	0.019	-0.174	0.067
Component 16	1%		Component 16	0.055	-0.004	0.102	-0.144	-0.066	0.034	0.104	-0.217	-0.190	-0.190	0.105	0.093	-0.221	0.813	0.194	-0.051	0.122	-0.074	0.197	-0.035
Component 17	0%		Component 17	0.221	0.041	0.348	0.024	0.040	-0.612	0.153	-0.149	-0.199	-0.149	0.181	0.262	-0.268	-0.278	0.021	0.001	0.166	-0.109	-0.231	-0.032
Component 18	0%		Component 18	0.055	0.368	-0.237	0.048	-0.088	-0.302	0.083	-0.047	0.026	0.095	-0.087	0.224	0.619	0.268	0.086	-0.076	0.019	0.055	-0.335	0.208
Component 19	0%		Component 19	0.104	0.315	0.058	-0.100	0.100	0.316	0.054	-0.684	0.333	-0.099	0.039	0.149	0.039	-0.257	0.075	-0.017	0.091	-0.030	0.194	0.176
Component 20	0%		Component 20	-0.111	-0.066	-0.038	0.152	0.004	-0.359	0.060	-0.028	0.802	0.026	-0.018	-0.176	-0.283	0.214	0.021	-0.012	-0.087	0.080	-0.094	-0.020

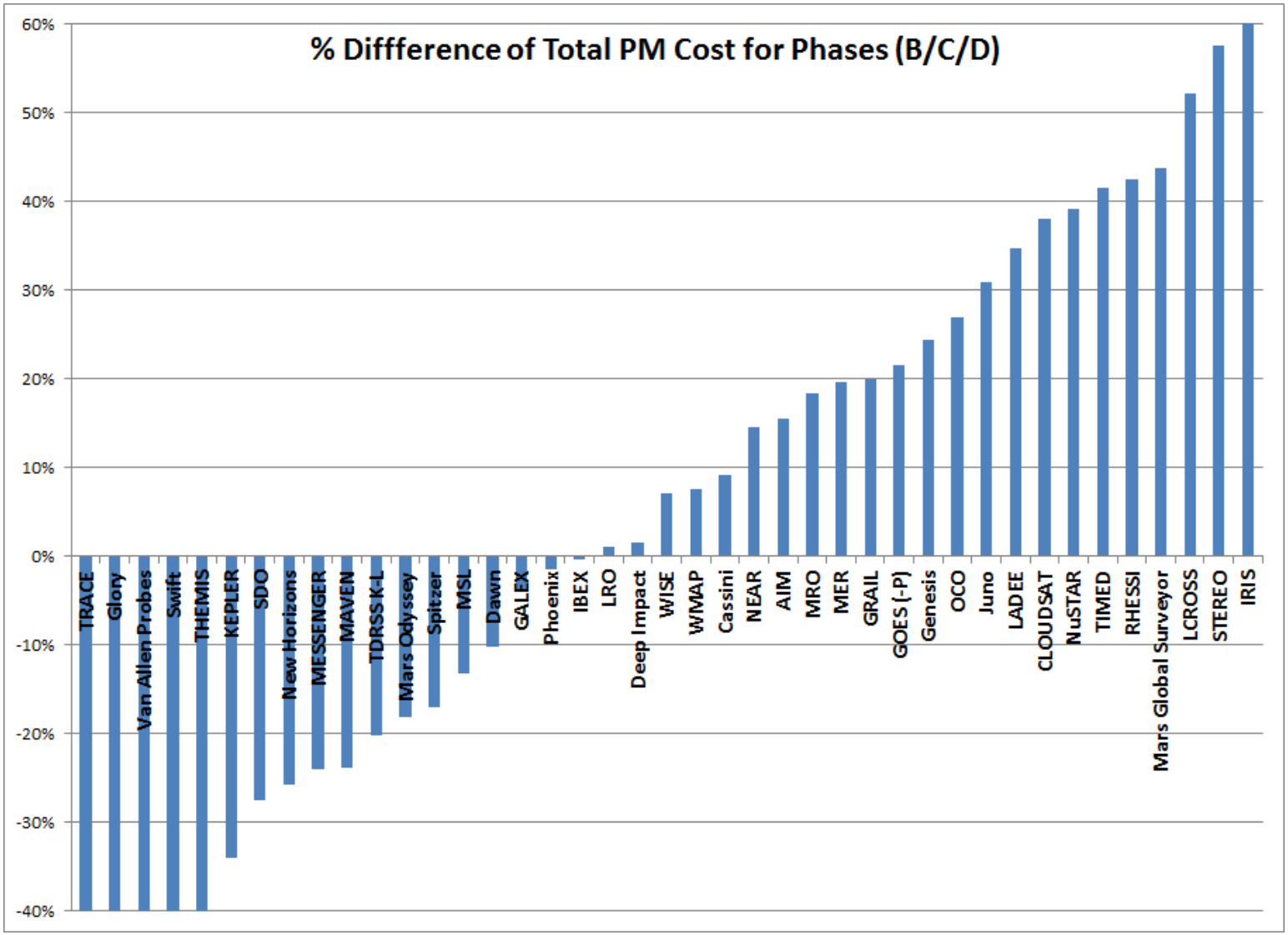
Variance Explained by PCA Components



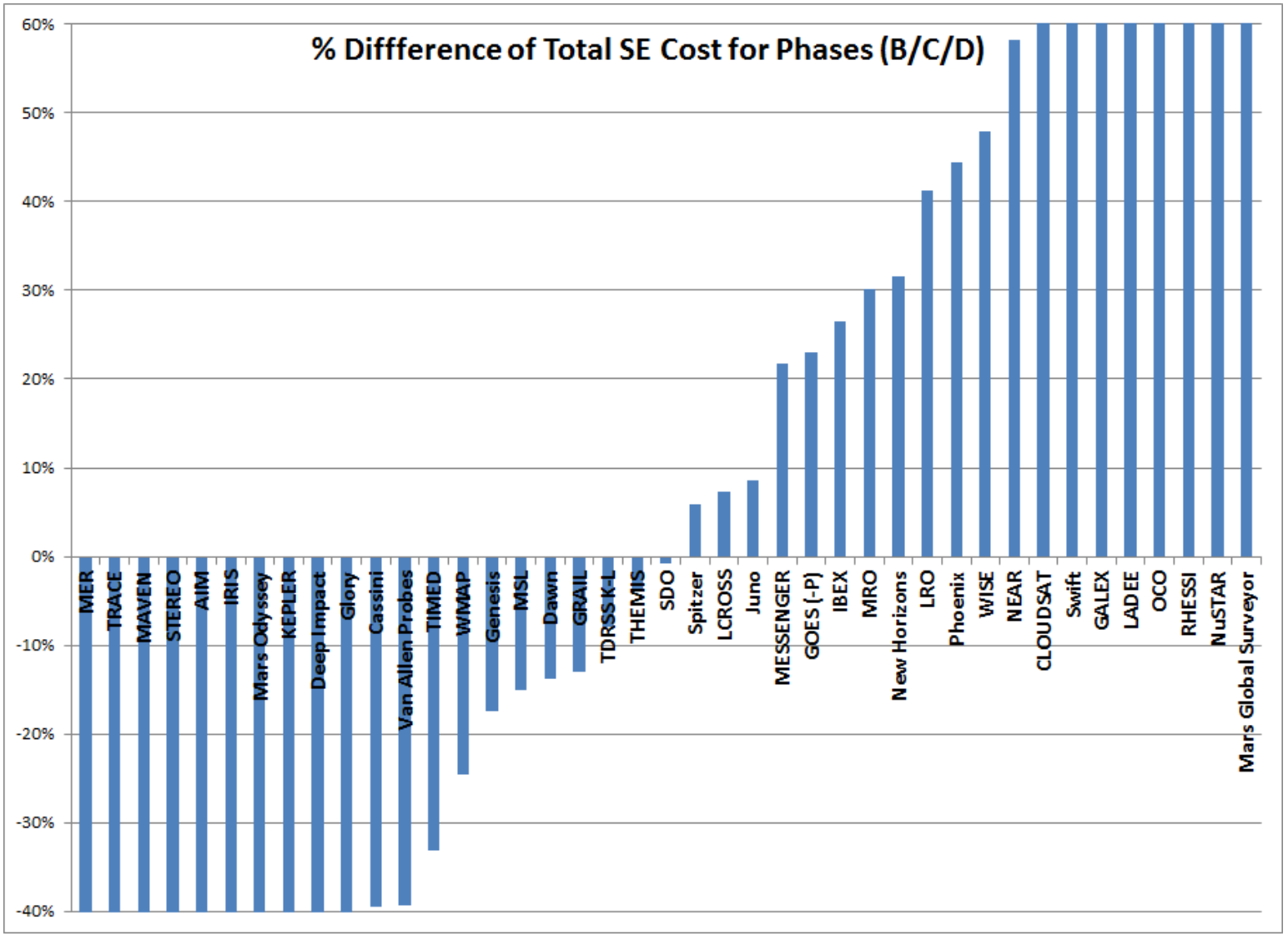
PCA Approach Results
Total PM/SE/MA/I&T for Phase B/C/D



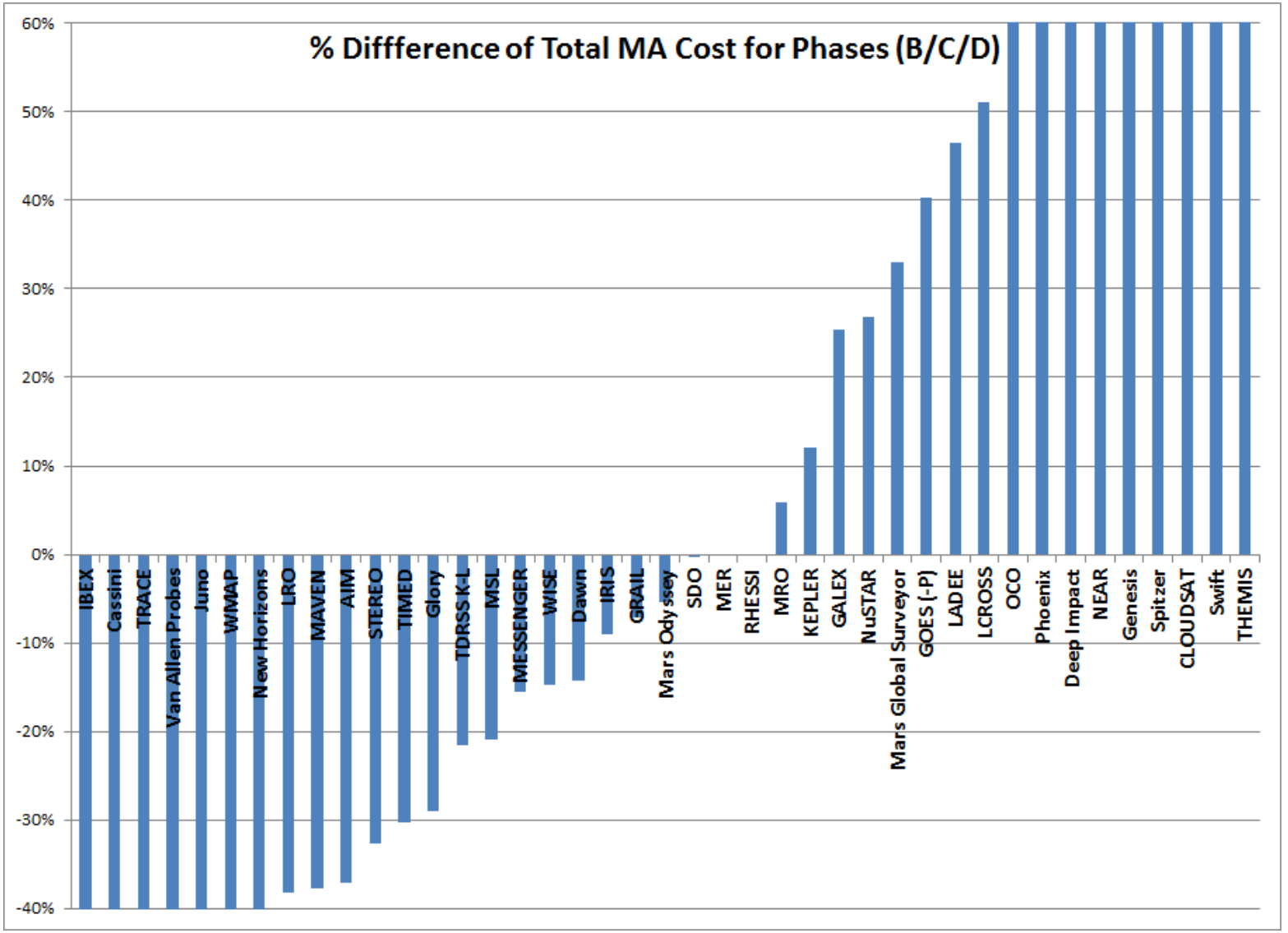
PCA Approach Results – Total PM for Phase B/C/D



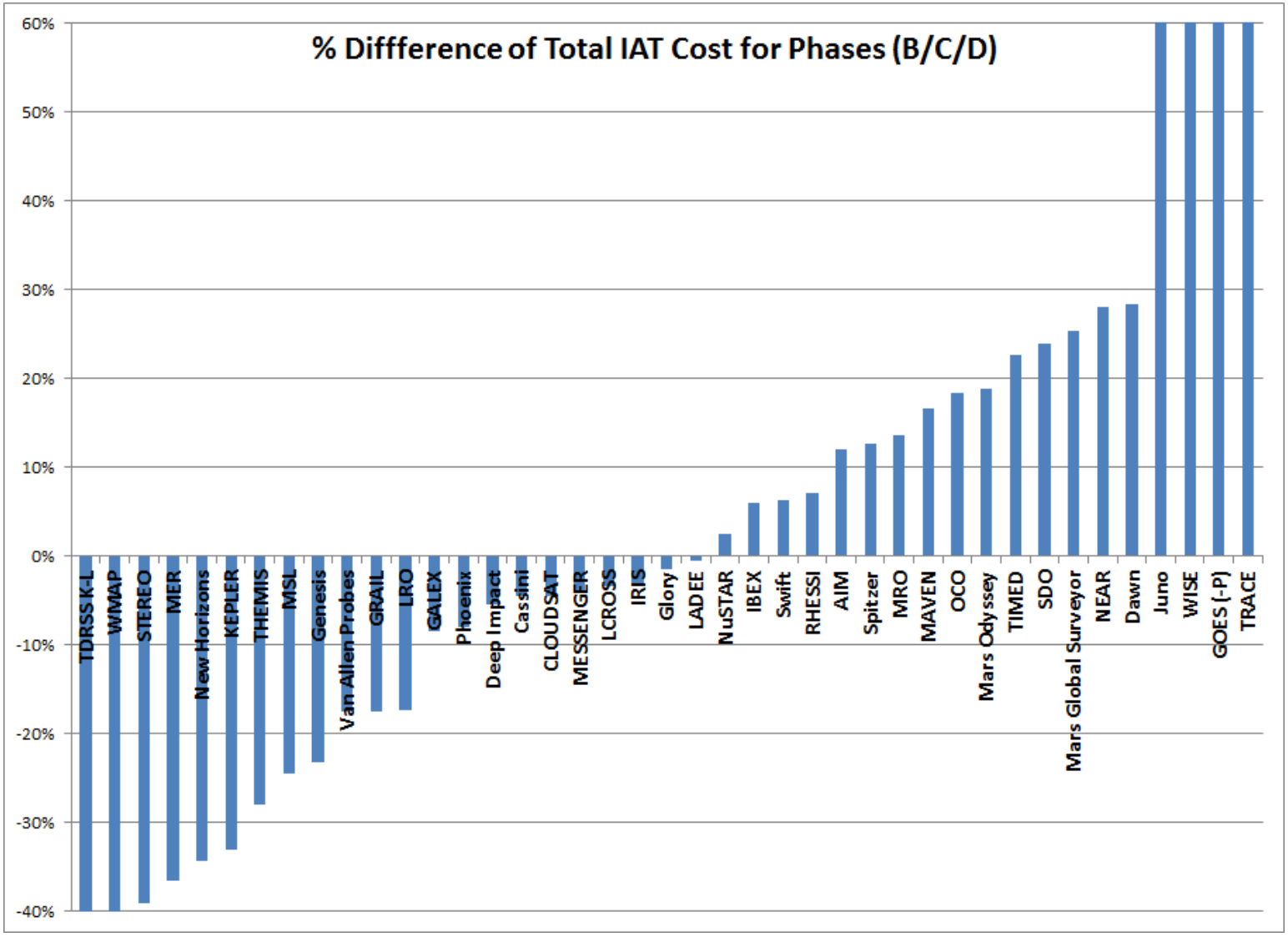
PCA Approach Results – Total SE for Phase B/C/D



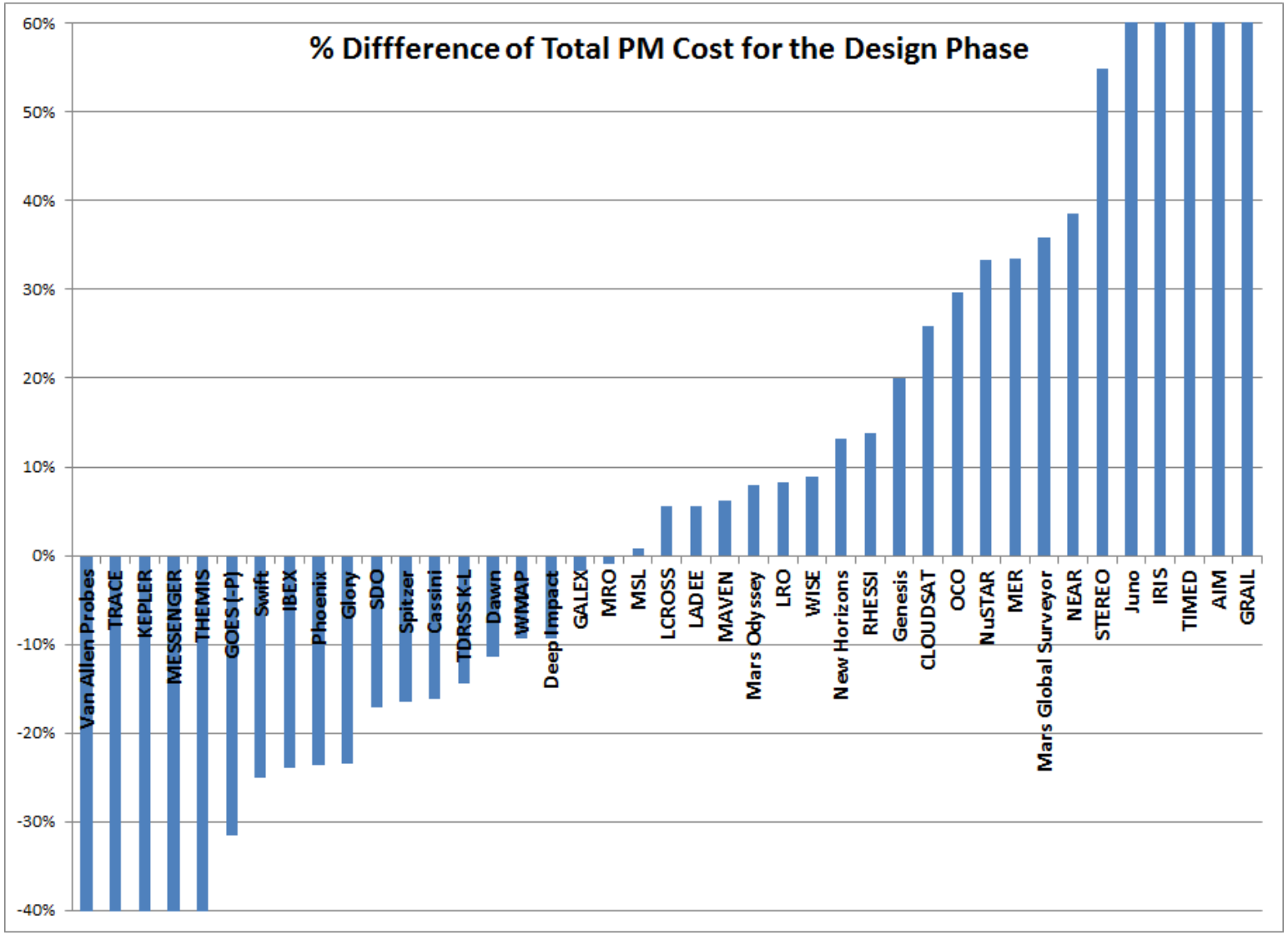
PCA Approach Results – Total MA for Phase B/C/D



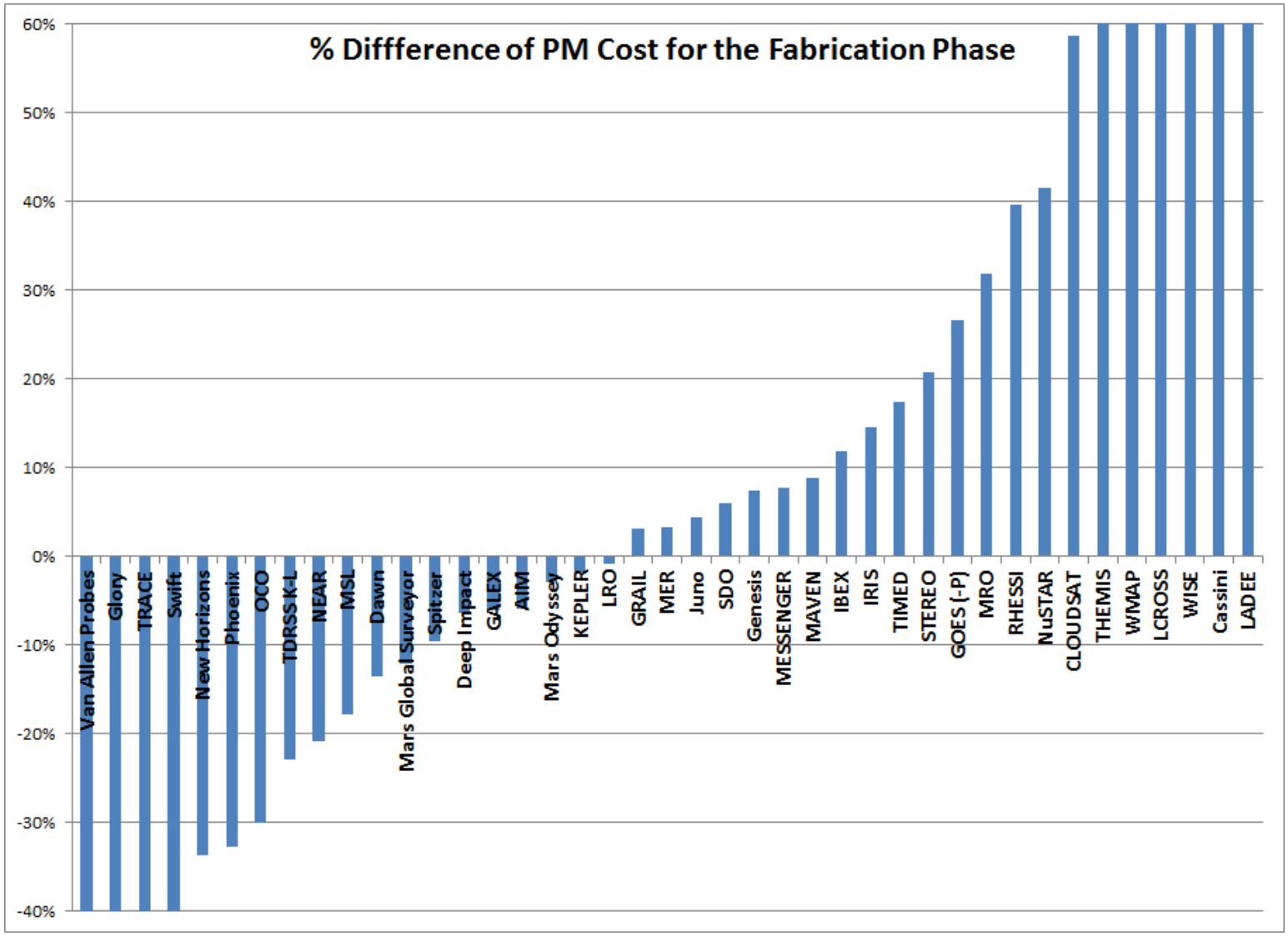
PCA Approach Results – Total I&T for Phase B/C/D



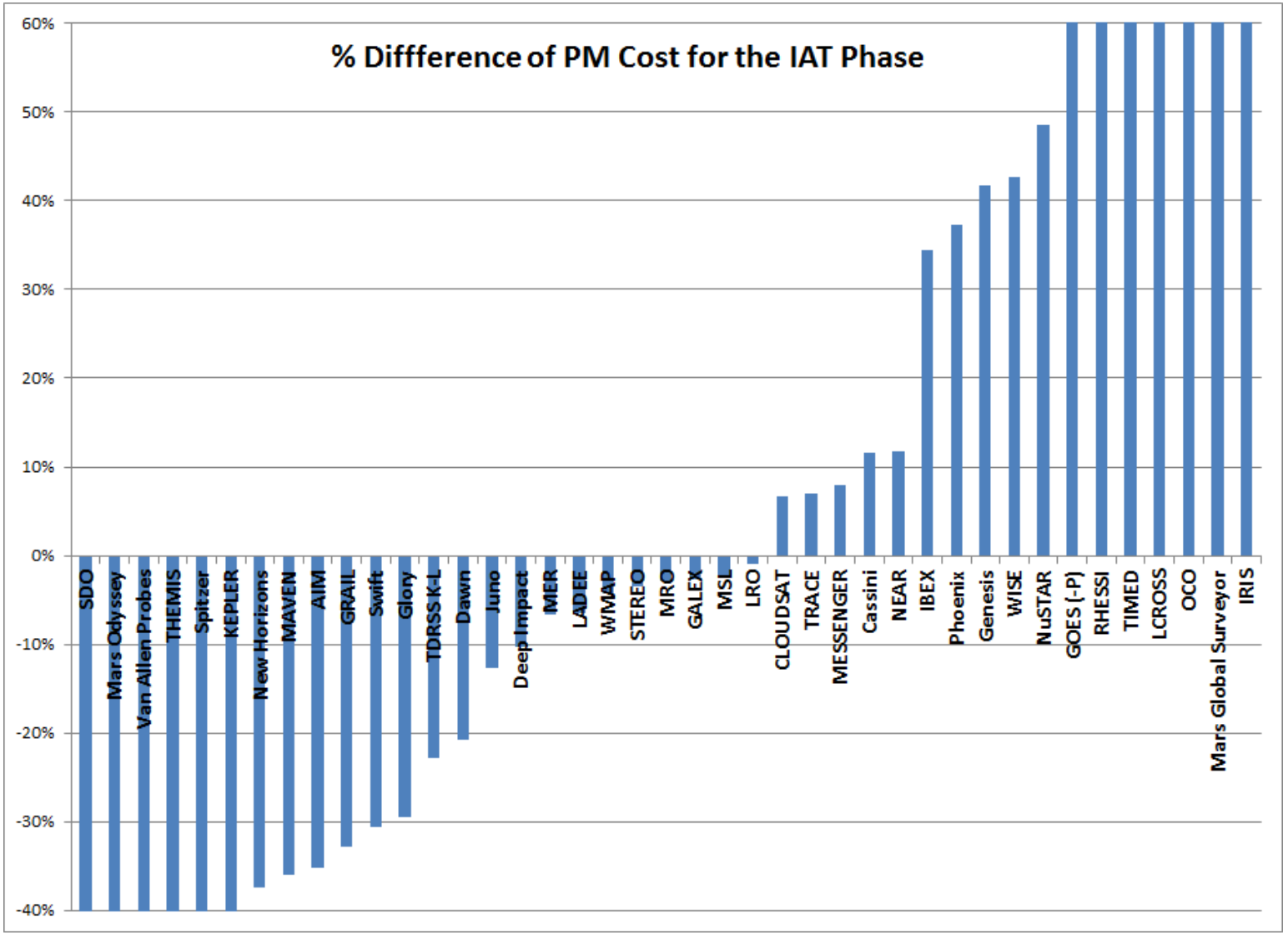
PCA Approach Results – PM for the Design Phase



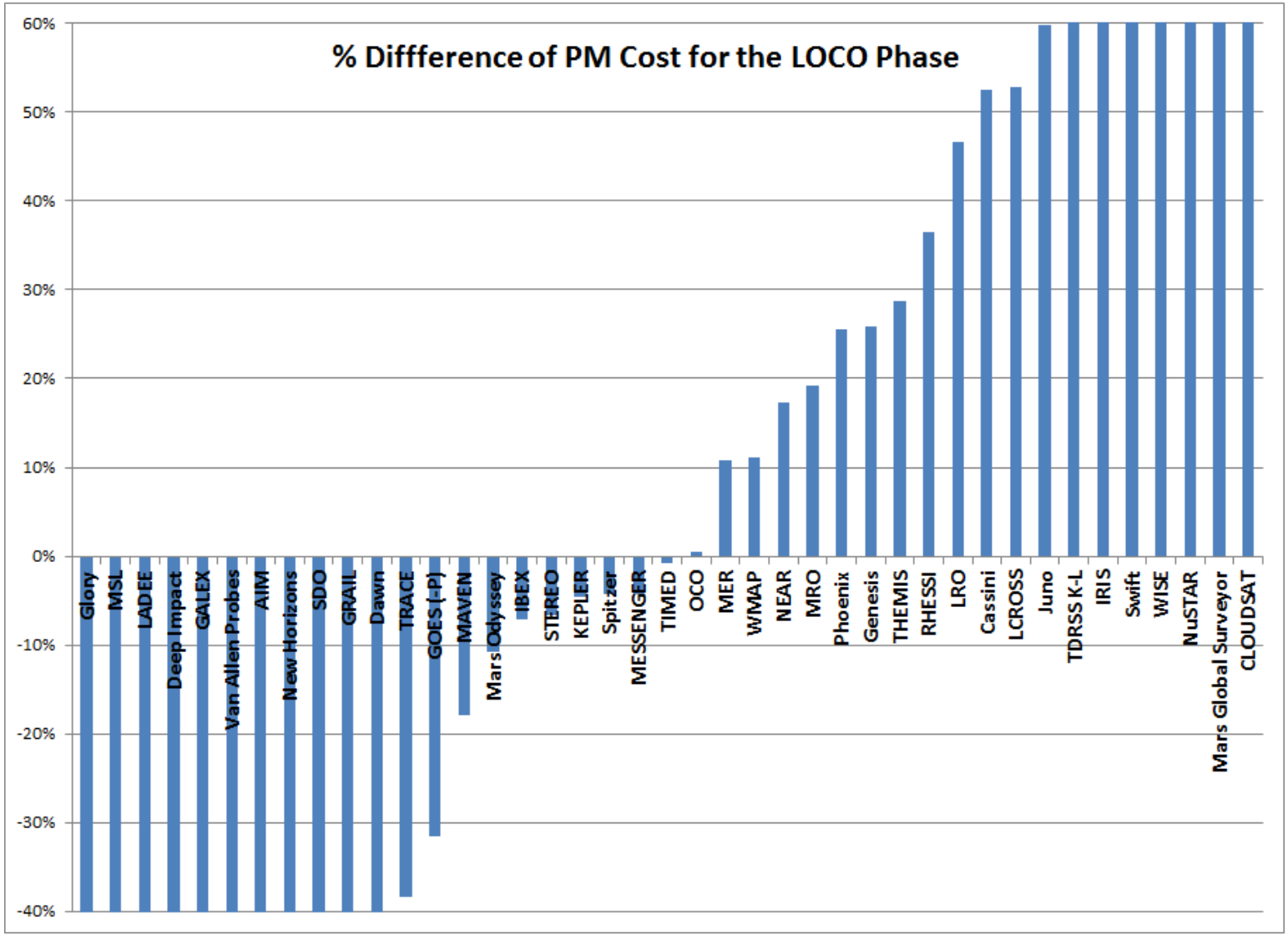
PCA Approach Results – PM for the Fabrication Phase



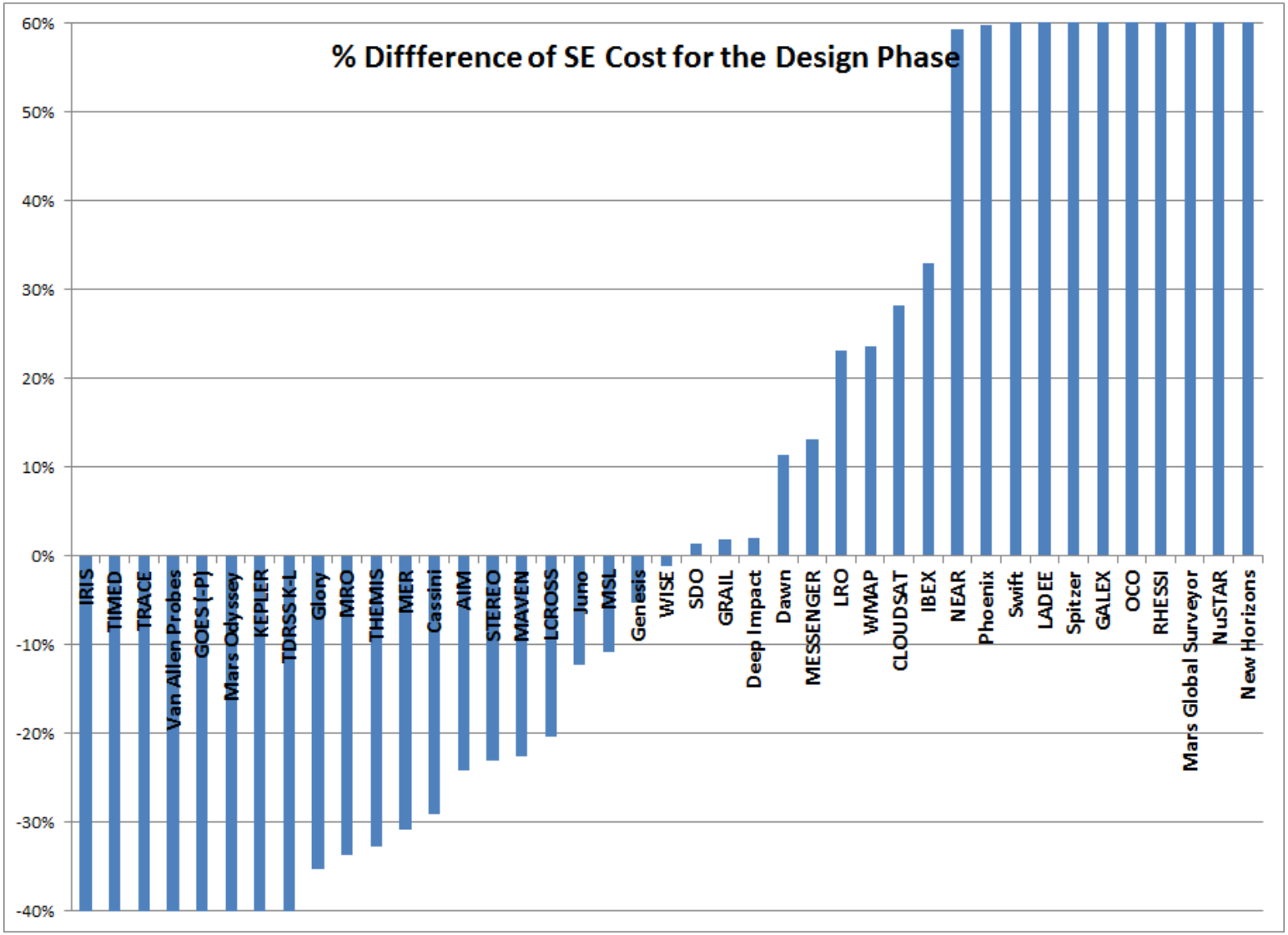
PCA Approach Results – PM for the I&T Phase



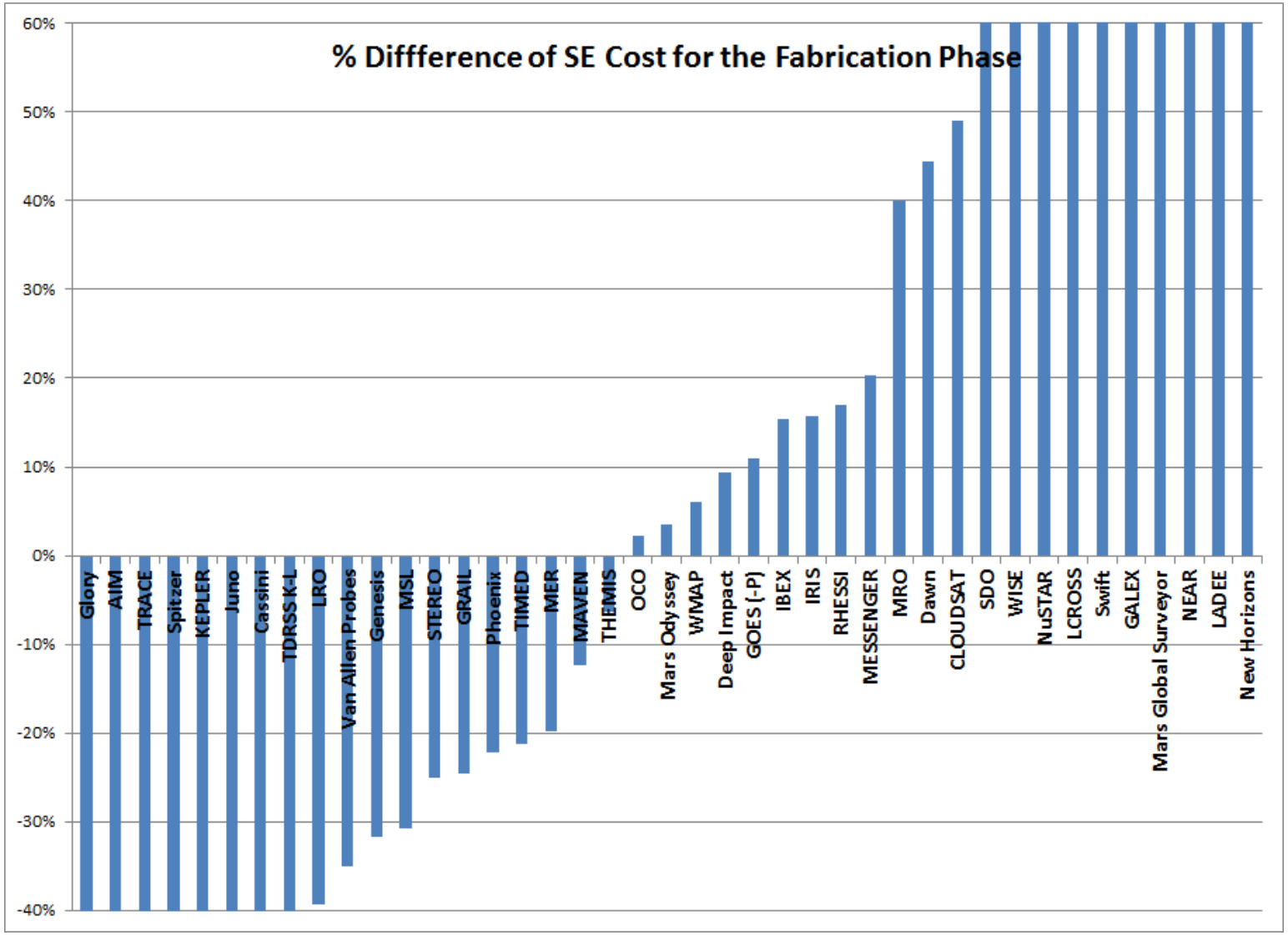
PCA Approach Results – PM for the LOCO Phase



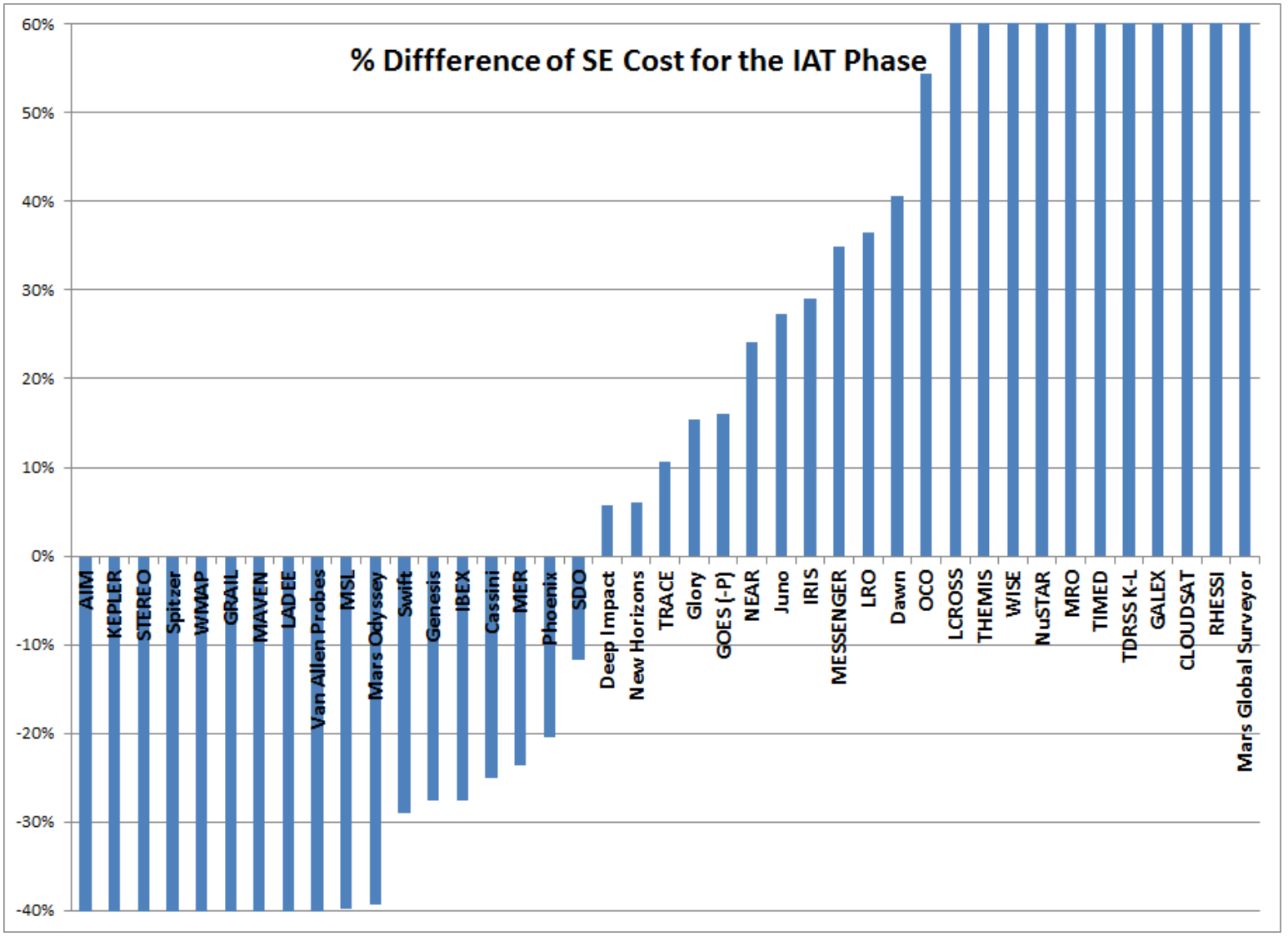
PCA Approach Results – SE for the Design Phase



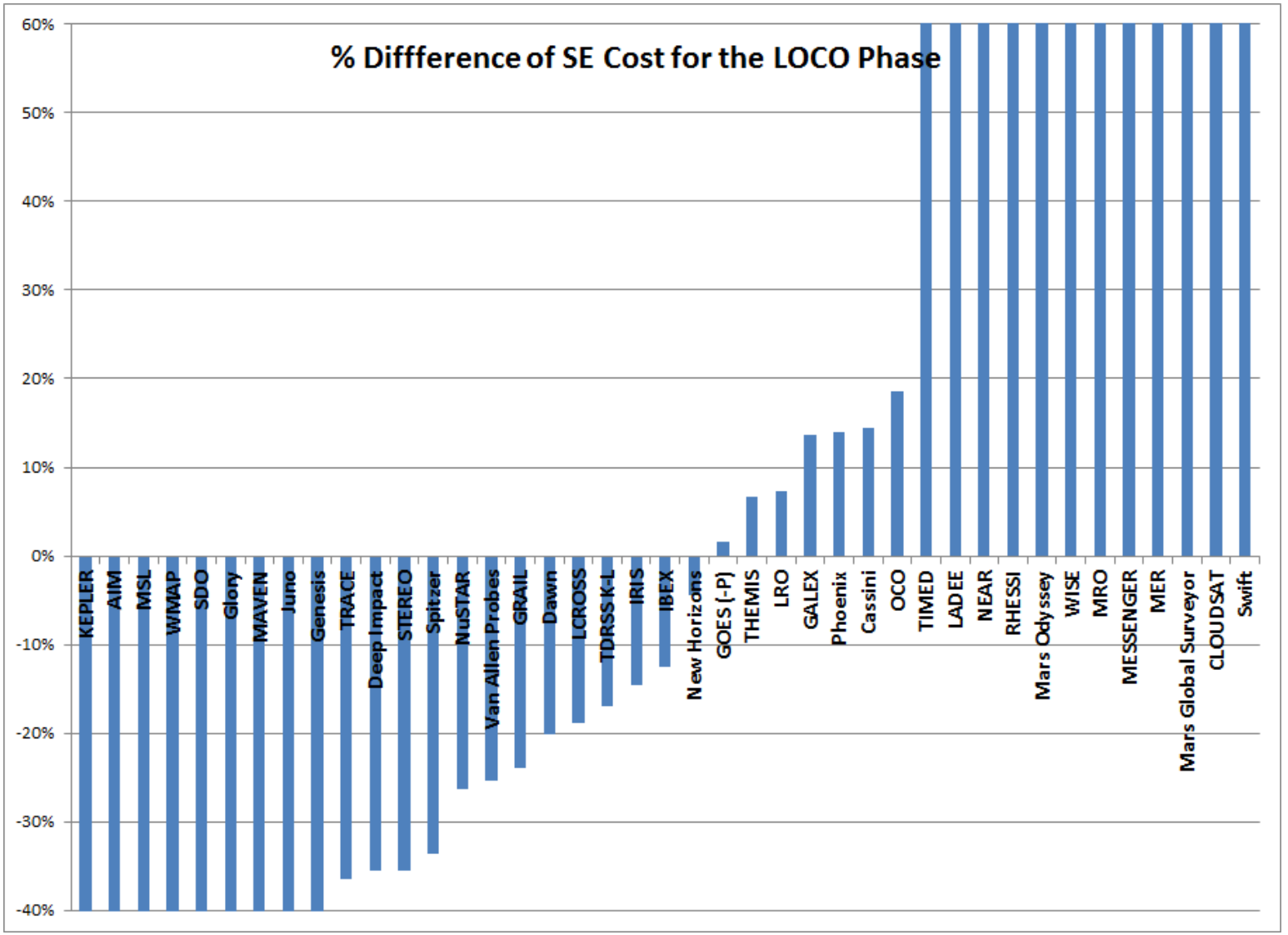
PCA Approach Results – SE for the Fabrication Phase



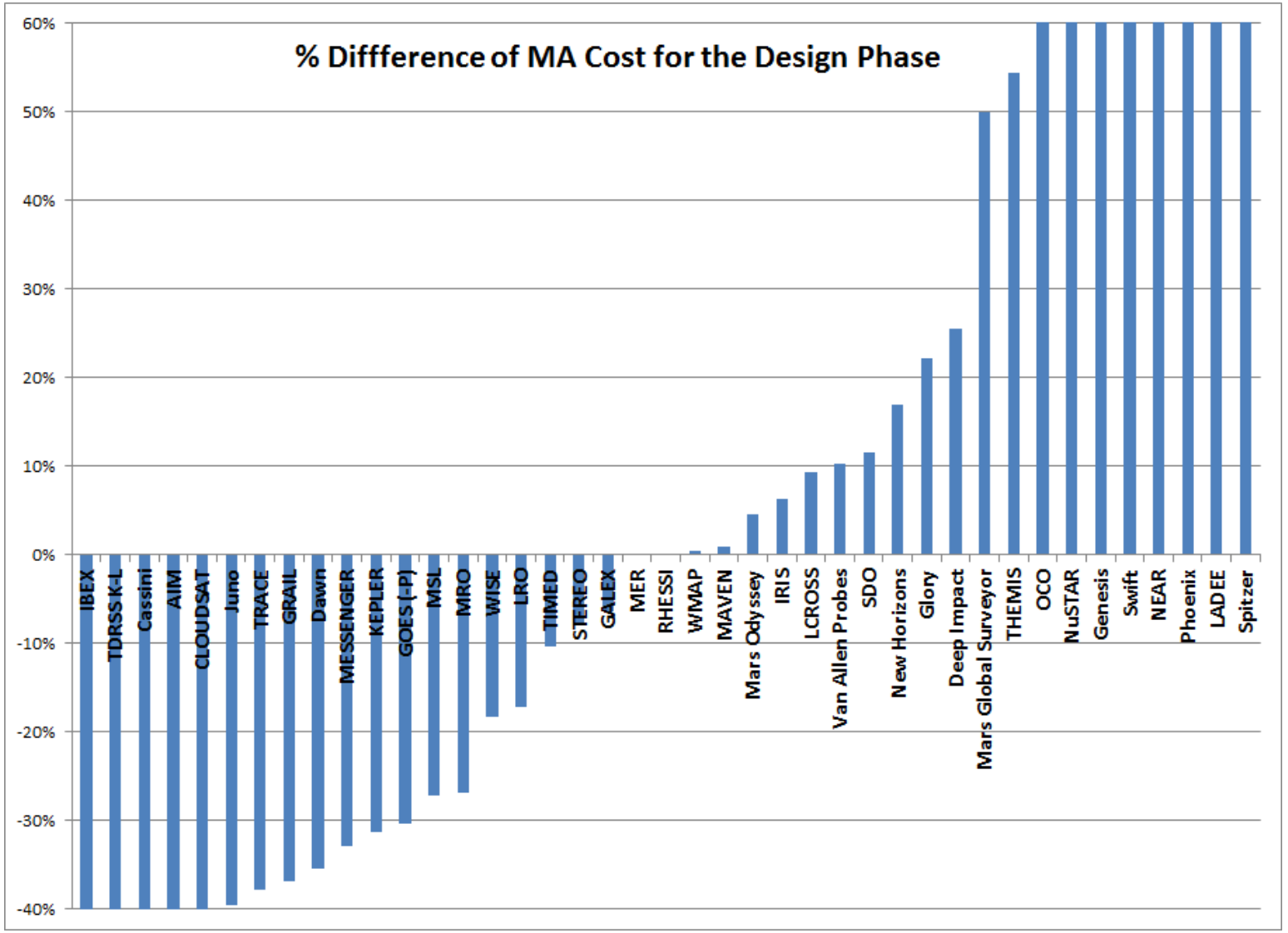
PCA Approach Results – SE for the I&T Phase



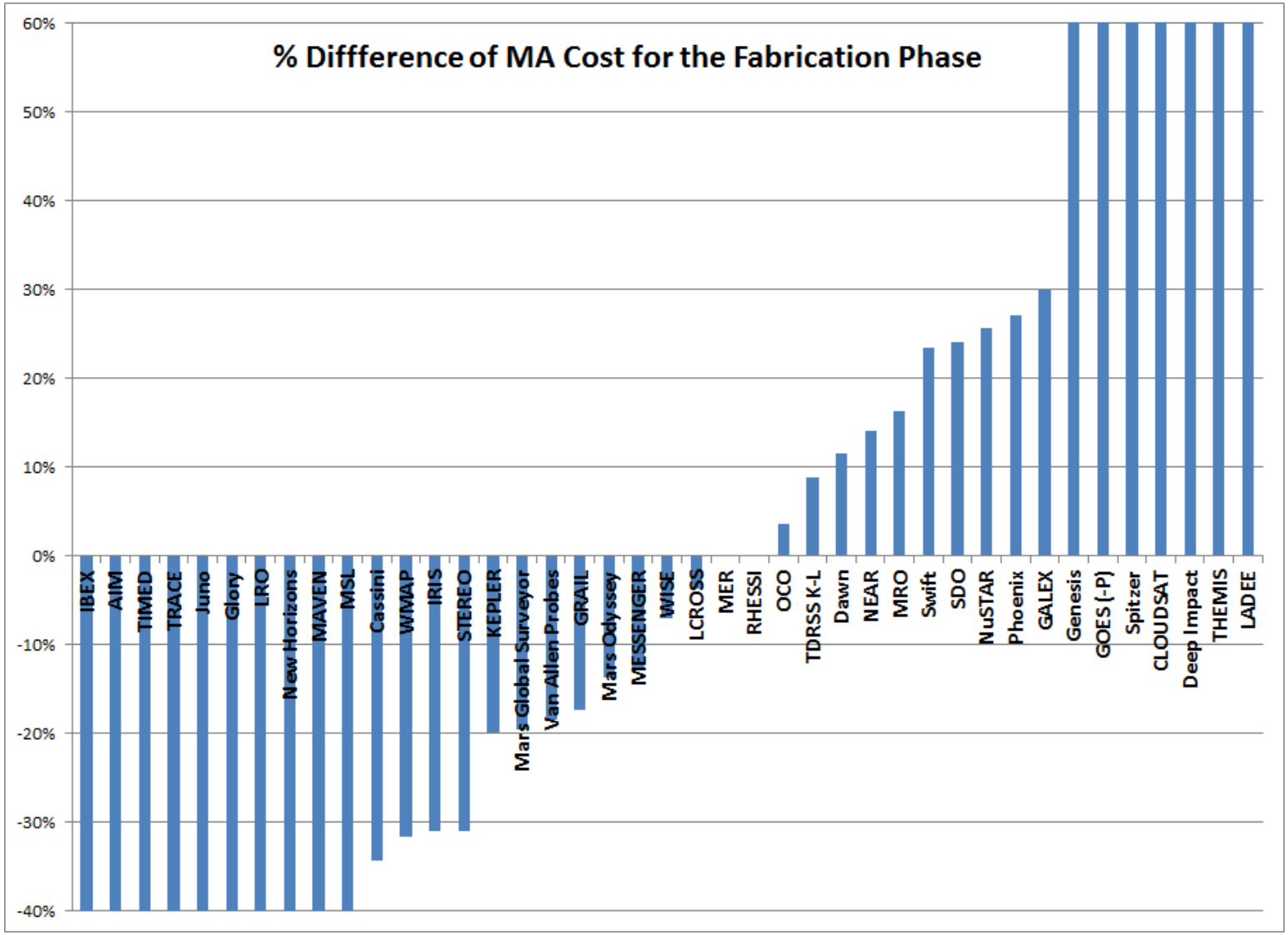
PCA Approach Results – SE for the LOCO Phase



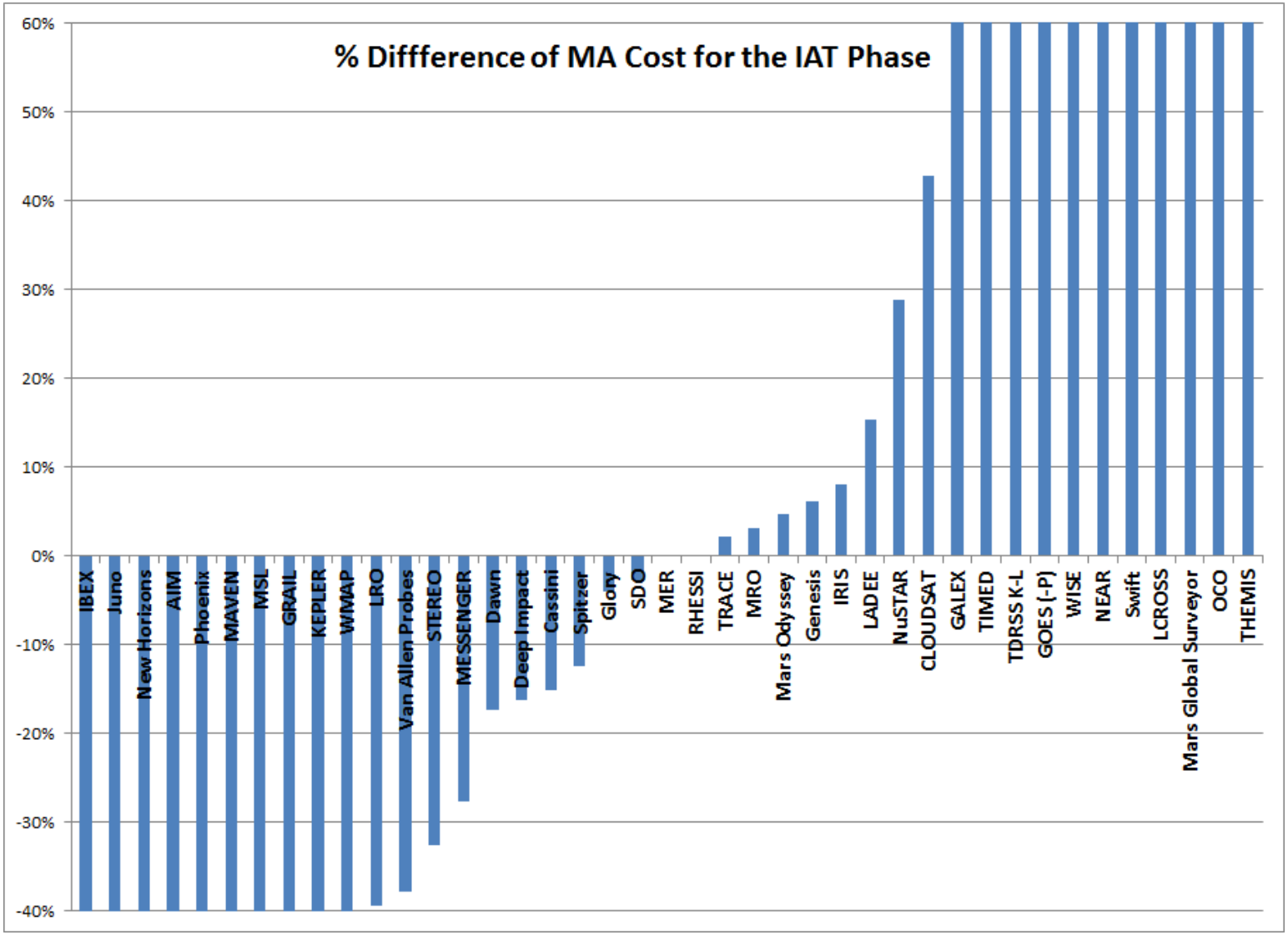
PCA Approach Results – MA for the Design Phase



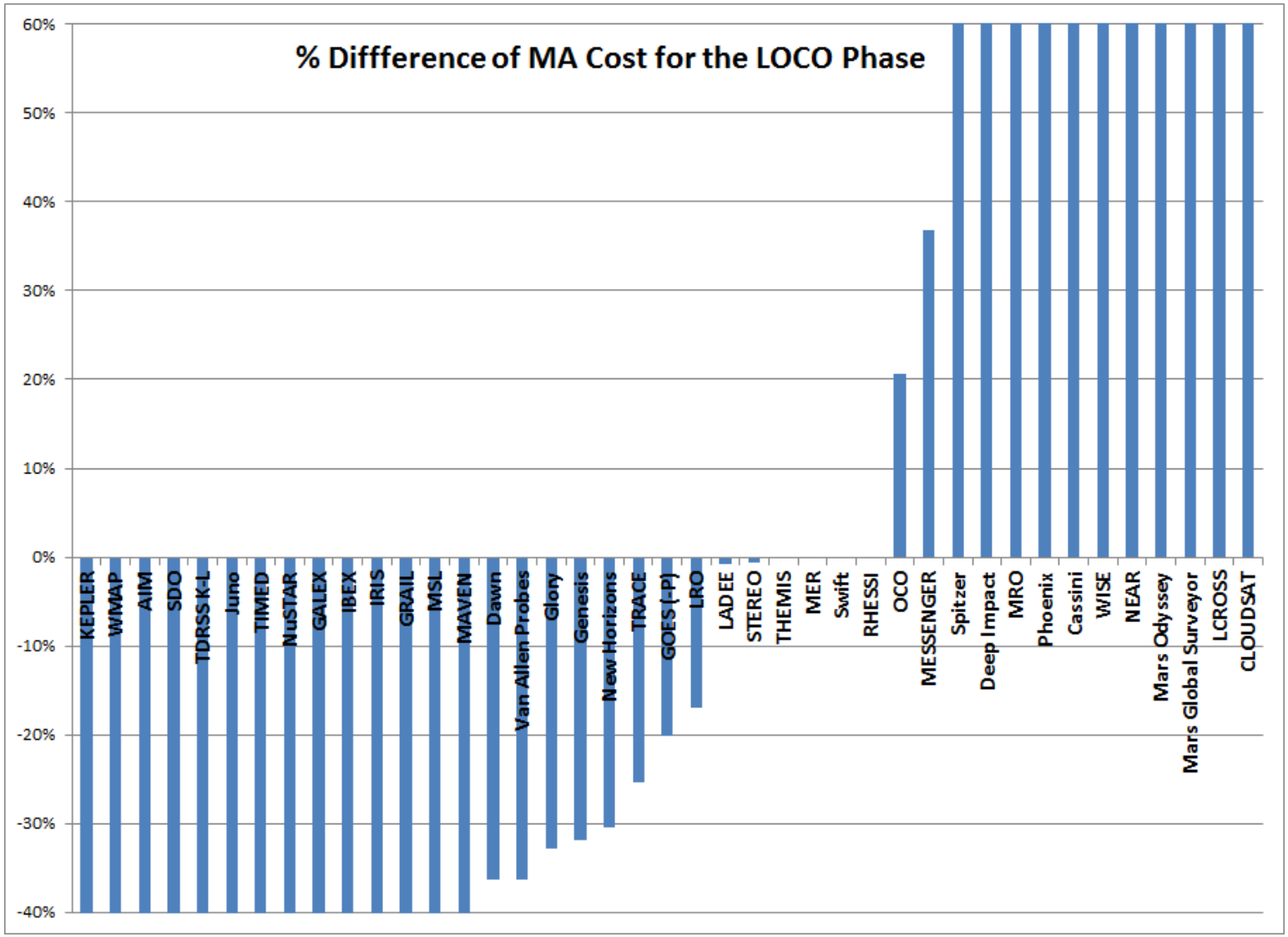
PCA Approach Results – MA for the Fabrication Phase



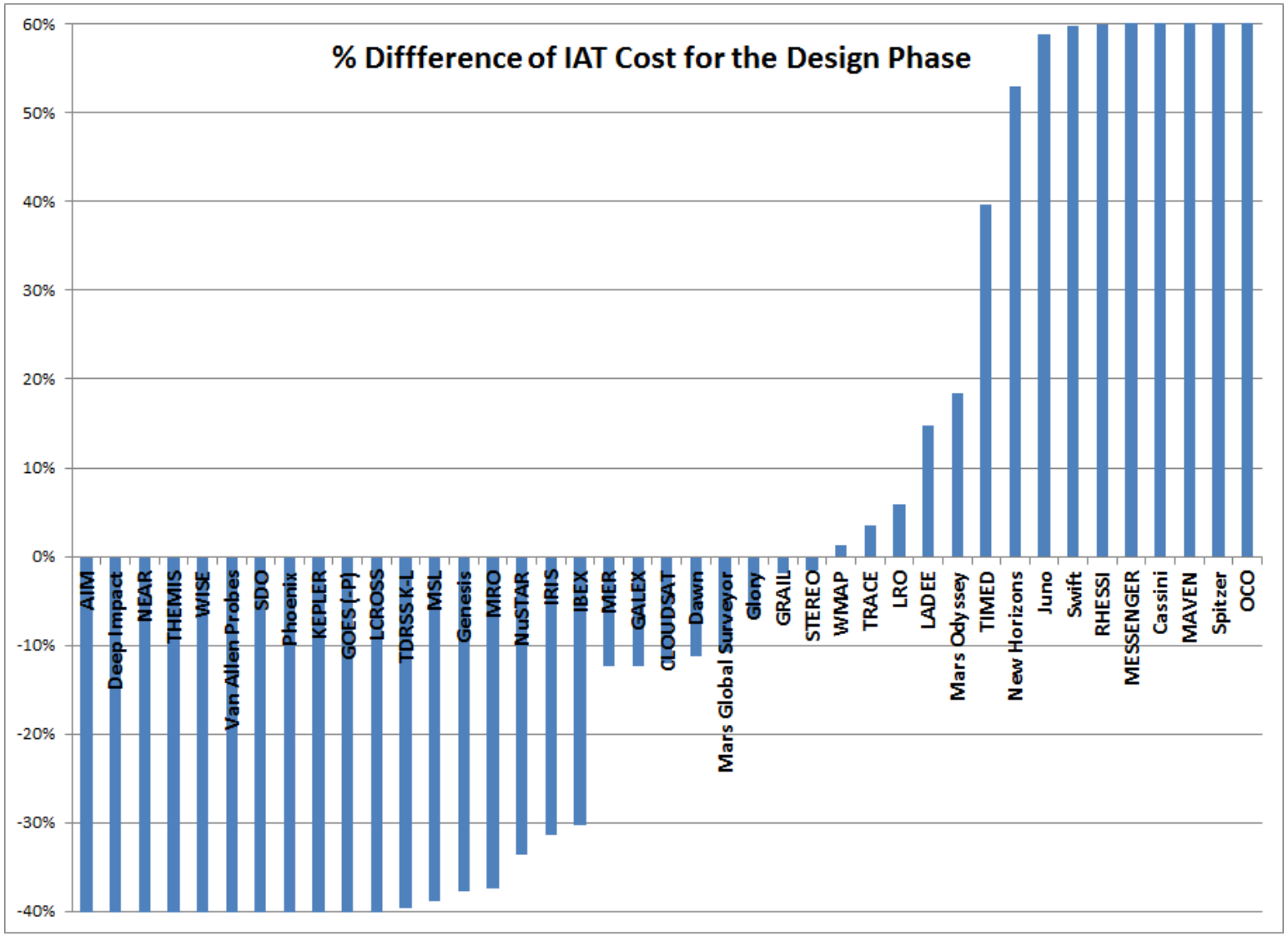
PCA Approach Results – MA for the I&T Phase



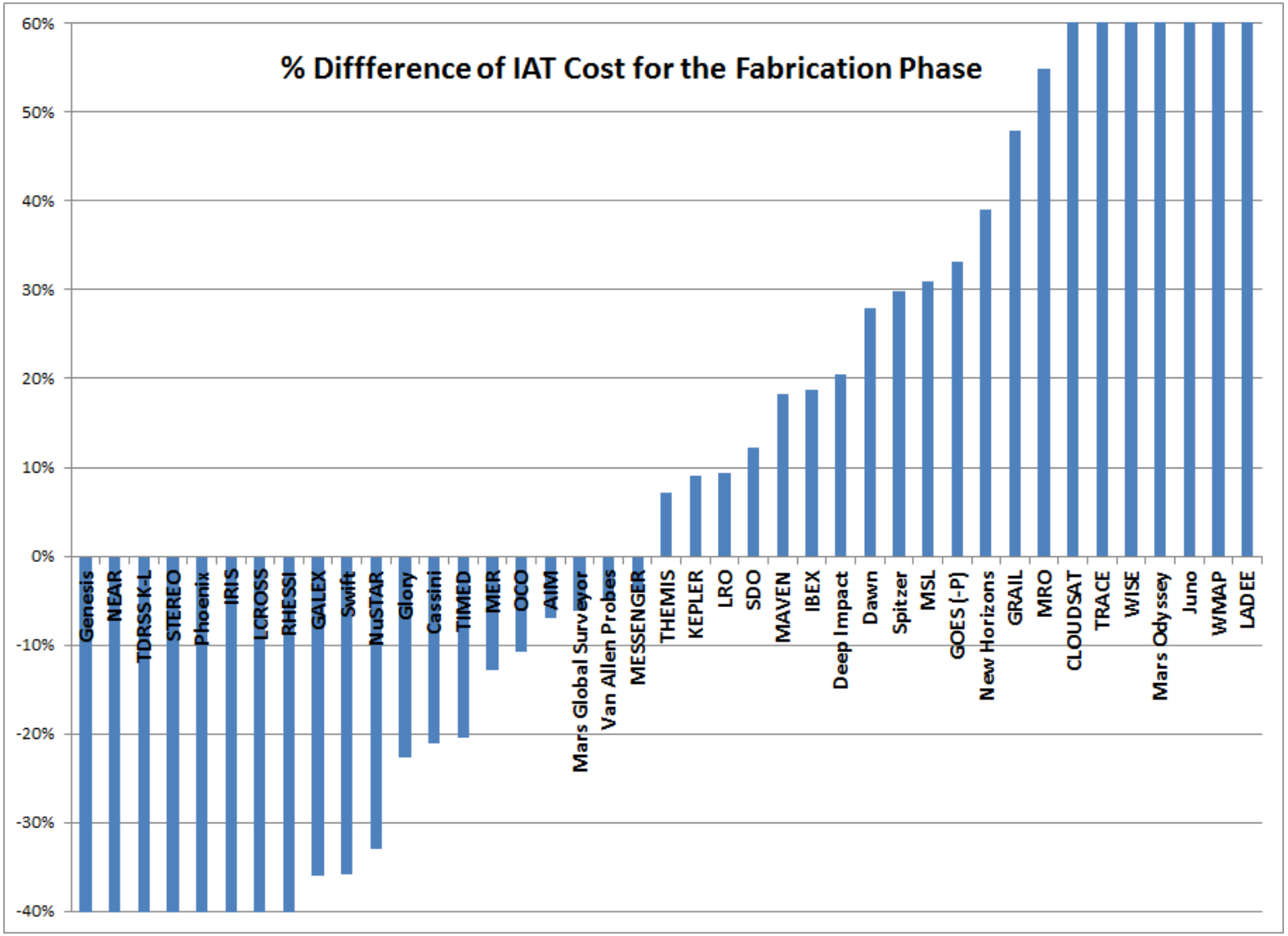
PCA Approach Results – MA for the LOCO Phase



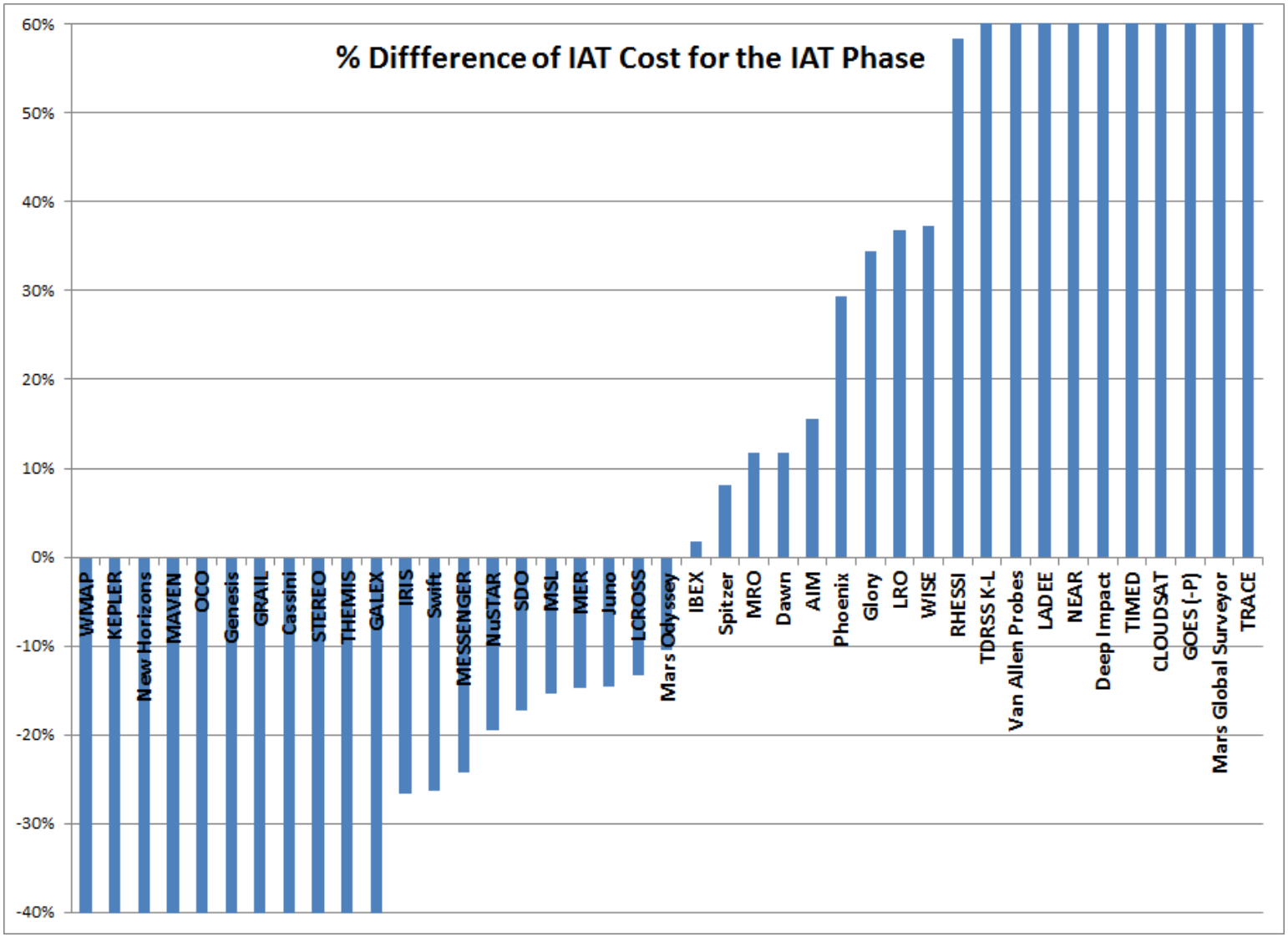
PCA Approach Results – I&T for the Design Phase



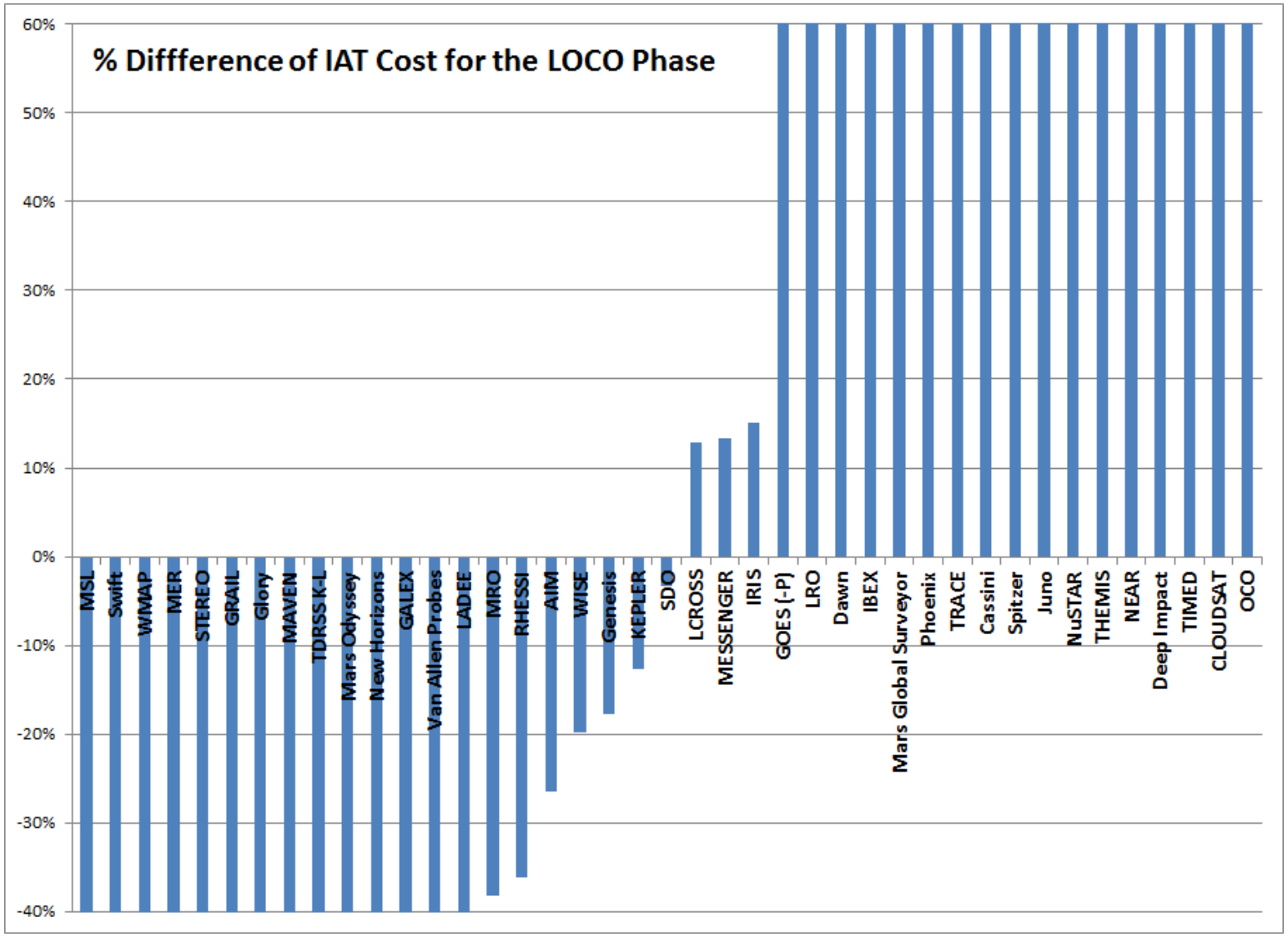
PCA Approach Results – I&T for the Fabrication Phase



PCA Approach Results – I&T for the I&T Phase



PCA Approach Results – I&T for the LOCO Phase



PCA Support Function CERs – Level 1 /2

Parameters	Total PM	Total SE	Total MA	Total IAT	Total PM/SE/MA/IAT
Parameter 1	FLIGHT SYSTEM TYPE	MISSION RISK CLASS	LEAD ORGANIZATION	DIRECTED or AO	MISSION RISK CLASS
Parameter 2	LEAD ORGANIZATION	LEAD ORGANIZATION	PARTS RATING	MISSION DESTINATION	MISSION DESTINATION
Parameter 3	FLIGHT SYSTEM ORGANIZATION	FLIGHT SYSTEM ORGANIZATION	-	FLIGHT SYSTEM ORGANIZATION	LEAD ORGANIZATION
Parameter 4	FLIGHT SYSTEM HERITAGE & TRL	# OF PAYLOAD ELEMENTS	-	FLIGHT SYSTEM POWER	FLIGHT SYSTEM ORGANIZATION
Parameter 5	PARTS RATING	-	-	PAYLOAD MASS	FLIGHT SYSTEM POWER
Parameter 6	-	-	-	# OF PAYLOAD ELEMENTS	# OF PAYLOAD ELEMENTS
Parameter 7	-	-	-	# OF KEY PAYLOAD CONTRACTORS	-

Factors	Total PM	Total SE	Total MA	Total IAT	Total PM/SE/MA/IAT
α	-0.4491	-0.6289	1.0714	-0.4174	-0.3374
β	0.5073	1.6227	1.4507	0.5089	0.3264
γ	1.391	0.7725	-	1.0959	0.6317
δ	-0.4	0.3192	-	0.3182	0.8013
ε	0.5882	-	-	0.2264	0.1818
ζ	-	-	-	0.5159	0.1647
η	-	-	-	-0.2824	-
Constant	3.8485	3.1888	1.8207	0.83	4.2309

- Equations take the form of:
  - LN($/mo) = α·LN(Parameter 1) + β·LN(Parameter 2) +……..+ Constant
- For example, the equation for Total MA would be:
  - Total MA Cost ($/mo FY14) = $e^{1.0714 \cdot LN(LEAD\ ORG.) + 1.4507 \cdot LN(PARTS\ RATING) + 1.8207}$

PCA Support Function CERs – Level 3 (PM)

Parameters	PM - Design	PM - Fabrication	PM - IAT	PM - LOCO	Total PM
Parameter 1	FLIGHT SYSTEM TYPE	MISSION RISK CLASS	DIRECTED or AO	DIRECTED or AO	FLIGHT SYSTEM TYPE
Parameter 2	FLIGHT SYSTEM ORGANIZATION	FLIGHT SYSTEM TYPE	LEAD ORGANIZATION	LEAD ORGANIZATION	LEAD ORGANIZATION
Parameter 3	FLIGHT SYSTEM HERITAGE & TRL	FLIGHT SYSTEM ORGANIZATION	FLIGHT SYSTEM ORGANIZATION	FLIGHT SYSTEM ORGANIZATION	FLIGHT SYSTEM ORGANIZATION
Parameter 4	PARTS RATING	FLIGHT SYSTEM POWER	# OF KEY PAYLOAD CONTRACTORS	PAYLOAD ORG.	FLIGHT SYSTEM HERITAGE & TRL
Parameter 5	# OF KEY PAYLOAD CONTRACTORS	PARTS RATING	-	# OF KEY PAYLOAD CONTRACTORS	PARTS RATING
Parameter 6	IN-HOUSE SCOPE	PAYLOAD MASS	-	IN-HOUSE SCOPE	-
Parameter 7	-	PAYLOAD POWER	-	-	-
Parameter 8	-	IN-HOUSE SCOPE	-	-	-

Factors	PM - Design	PM - Fabrication	PM - IAT	PM - LOCO	Total PM
α	-0.8136	0.7634	-0.5253	-0.779	-0.4491
β	2.1938	-0.5482	0.7998	1.1021	0.5073
γ	-0.6258	2.3989	1.3229	1.5468	1.391
δ	0.7004	0.2107	0.4001	-0.6091	-0.4
ε	-0.3077	1.1472	-	0.4181	0.5882
ζ	0.5733	0.2758	-	0.8902	-
η	-	-0.2687	-	-	-
θ	-	0.6619	-	-	-
Constant	3.6442	-0.7276	3.1145	1.907	3.8485

- Equations take the form of:
  - LN($/mo) = α·LN(Parameter 1) + β·LN(Parameter 2) +……..+ Constant

PCA Support Function CERs – Level 3 (SE)

Engineering Cost Office

Parameters	SE - Design	SE - Fabrication	SE - IAT	SE - LOCO	Total SE
Parameter 1	MISSION RISK CLASS	MISSION DESTINATION	LEAD ORGANIZATION	MISSION RISK CLASS	MISSION RISK CLASS
Parameter 2	LEAD ORGANIZATION	LEAD ORGANIZATION	FLIGHT SYSTEM ORGANIZATION	FLIGHT SYSTEM TYPE	LEAD ORGANIZATION
Parameter 3	FLIGHT SYSTEM ORGANIZATION	FLIGHT SYSTEM POWER	FLIGHT SYSTEM MASS	LEAD ORGANIZATION	FLIGHT SYSTEM ORGANIZATION
Parameter 4	PAYLOAD MASS	FLIGHT SYSTEM HERITAGE & TRL	PAYLOAD POWER	PAYLOAD ORG.	# OF PAYLOAD ELEMENTS
Parameter 5	-	PAYLOAD POWER	-	PAYLOAD MASS	-
Parameter 6	-	# OF PAYLOAD ELEMENTS	-	-	-
Parameter 7	-	# OF KEY PAYLOAD CONTRACTORS	-	-	-
Parameter 8	-	-	-	-	-

Factors	SE - Design	SE - Fabrication	SE - IAT	SE - LOCO	Total SE
α	-1.324	0.6258	1.2542	-1.8003	-0.6289
β	1.1828	1.1785	1.2551	1.3716	1.6227
γ	1.0758	0.6153	0.7568	2.7664	0.7725
δ	-0.2956	0.9679	-0.4485	-1.1355	0.3192
ε	-	-0.3596	-	-0.8098	-
ζ	-	0.476	-	-	-
η	-	-0.398	-	-	-
θ	-	-	-	-	-
Constant	5.4663	0.4832	0.3218	7.0029	3.1888

- Equations take the form of:
  - LN($/mo) = α·LN(Parameter 1) + β·LN(Parameter 2) +……..+ Constant

PCA Support Function CERs – Level 3 (MA)

Parameters	MA - Design	MA - Fabrication	MA - IAT	MA - LOCO	Total MA
Parameter 1	MISSION RISK CLASS	LEAD ORGANIZATION	LEAD ORGANIZATION	MISSION RISK CLASS	LEAD ORGANIZATION
Parameter 2	MISSION DESTINATION	PARTS RATING	PAYLOAD ORG.	FLIGHT SYSTEM TYPE	PARTS RATING
Parameter 3	LEAD ORGANIZATION	-	FLIGHT SYSTEM POWER	LEAD ORGANIZATION	-
Parameter 4	PAYLOAD MASS	-	-	PAYLOAD ORG.	-
Parameter 5	IN-HOUSE SCOPE	-	-	PAYLOAD MASS	-
Parameter 6	-	-	-	-	-
Parameter 7	-	-	-	-	-
Parameter 8	-	-	-	-	-

Factors	MA - Design	MA - Fabrication	MA - IAT	MA - LOCO	Total MA
α	-0.9512	0.7966	1.7141	-1.8436	1.0714
β	0.3816	1.9518	-0.5915	1.5967	1.4507
γ	1.3512	-	0.4153	2.6268	-
δ	-0.2082	-	-	-1.4256	-
ε	0.6263	-	-	-0.9669	-
ζ	1.265	-	-	-	-
η	0.531	-	-	-	-
θ	-0.319	-	-	-	-
Constant	4.4335	1.6211	1.4491	7.5113	1.8207

- Equations take the form of:
  - LN($/mo) = α·LN(Parameter 1) + β·LN(Parameter 2) +……..+ Constant

PCA Support Function CERs – Level 3 (I&T)

Parameters	IAT - Design	IAT - Fabrication	IAT - IAT	IAT - LOCO	Total IAT
Parameter 1	FLIGHT SYSTEM TYPE	MISSION RISK CLASS	FLIGHT SYSTEM TYPE	DIRECTED or AO	DIRECTED or AO
Parameter 2	FLIGHT SYSTEM ORGANIZATION	FLIGHT SYSTEM ORGANIZATION	FLIGHT SYSTEM MASS	MISSION RISK CLASS	MISSION DESTINATION
Parameter 3	PARTS RATING	FLIGHT SYSTEM POWER	# OF PAYLOAD ELEMENTS	FLIGHT SYSTEM TYPE	FLIGHT SYSTEM ORGANIZATION
Parameter 4	-	PARTS RATING	IN-HOUSE SCOPE	# OF KEY PAYLOAD CONTRACTORS	FLIGHT SYSTEM POWER
Parameter 5	-	PAYLOAD MASS	-	-	PAYLOAD MASS
Parameter 6	-	PAYLOAD POWER	-	-	# OF PAYLOAD ELEMENTS
Parameter 7	-	# OF PAYLOAD ELEMENTS	-	-	# OF KEY PAYLOAD CONTRACTORS
Parameter 8	-	# OF KEY PAYLOAD CONTRACTORS	-	-	-

Factors	IAT - Design	IAT - Fabrication	IAT - IAT	IAT - LOCO	Total IAT
α	-1.1293	1.6112	0.9494	-2.0733	-0.4174
β	1.605	1.914	0.5801	-2.0785	0.5089
γ	1.8072	0.5159	0.4834	1.4943	1.0959
δ	-	1.4667	-1.047	1.1506	0.3182
ε	-	0.6233	-	-	0.2264
ζ	-	-0.4699	-	-	0.5159
η	-	0.9141	-	-	-0.2824
θ	-	-0.6018	-	-	-
Constant	1.1389	-4.3453	2.0337	5.2601	0.83

- Equations take the form of:
  - LN($/mo) = α·LN(Parameter 1) + β·LN(Parameter 2) +……..+ Constant